Annual Report 2010

Centre for Image Analysis

Centrum för bildanalys

Cover: Illustrations from two of the PhD theses presented at CBA during 2010. Further information in Section 4.2.

Top
Kristin Norell — An image depicted online at a sawmill measurements station. The pith and annual ring segments have been automatically detected on the Scots Pine end face.

Bottom
Magnus Gedda — A three dimensional electron tomography image of a protein in solution. A MET protein is localized and a curve model is constructed to determine the curvature of the protein.

Cover design:
Gustaf Kylberg

Edited by:
Ewert Bengtsson, Vladimir Curic, Ida-Maria Sintorn, Ingela Nyström, Robin Strand, Lena Wadelius, Erik Wernersson

Centre for Image Analysis, Uppsala, Sweden

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Contents

1 Introduction

1.1 General background

The Centre for Image Analysis (CBA) carries out research and graduate education in computerized image analysis and perceptualization. Our work ranges from the purely theoretical to methods, algorithms and systems for applications primarily in biomedicine and forestry.

CBA is collaboration between Uppsala University (UU) and the Swedish University of Agricultural Sciences (SLU) which started in 1988. Through this year we have been a single administrative unit with our administration carried out at UU but with employees at both universities. Our finances came in three roughly equal parts from the two universities and external grants, or more precisely 35% from UU, 25% from SLU and 40% grants for a total budget of about 20 MSEK.

During 2010 our two host universities decided to change our organization and from the beginning of 2011 we are two separate administrative units, one at each university. At UU we are a division within the Dept. of Information Technology and at SLU a yet to be defined entity. Our hosts have explicitly stated that this reorganization will not change our identity as a single research center, so we hope to continue our very close collaboration also in the future.

During 2010, a total of 39 persons have been working at CBA: 19 researchers, 18 PhD students and one administrator. Additionally, 12 Master thesis students have finished their thesis work with supervision from CBA. This does not mean, however, that we have had 51 full-time persons at CBA; many have split appointments, part time at CBA and part time elsewhere, most commonly at the Dept. of Information Technology. Some of our senior researchers have their main work place elsewhere but are retaining a small part time position at CBA mainly in order to supervise their PhD students until graduation. Last year CBA had about 23 full-time employees, not counting undergraduate teaching and Master thesis students. Most of us at CBA also pursue some undergraduate teaching that is organized by the Dept. of Information Technology at UU.

On average three-four PhD dissertations are produced each year. In 2010 two PhD theses were defended: Magnus Gedda at UU and Kristin Norell at SLU. This year Gunilla Borgefors served as conferrer at the traditional conferment ceremony at SLU when the new doctors receive their laurels, a once-in-a-lifetime honor.

Maria Axelsson received the Benzelius award from the Royal Society of Sciences in Uppsala for her PhD thesis. We were also pleased that two of our former PhD students, Anders Hast and Pasha Razifar, qualified as docents, bringing the total number of CBA docents to nine.

Image processing is highly interdisciplinary, with foundations in mathematics, statistics, physics, signal processing and computer science, and with applications in many diverse fields. We are working in a wide range of application areas, most of them related to life sciences and usually in close collaboration with domain experts. Our collaborators are found locally as well as nationally and internationally. For a complete list of our 46 national and 42 international collaborators see Section 5.7. One of our collaborating groups, Uppsala Multidisciplinary Center for Advanced Computational Science (UPPMAX), is located on our premises and is managed by Ingela Nyström and administrated by Lena Wadelius.

In theoretical research, we focus on discrete geometry and multi-dimensional images, in both the spatial and spectral domains. Over the last several years we have expanded our activities in perceptualization. During 2009 we started a new major project in this area, under leadership of visiting Professor Ingrid Carlbom, with the goal of creating an augmented reality system in which you can see, feel, and manipulate virtual 3D objects as if they were real using a haptic glove. This project has progressed very well during 2010 and we now have a first working prototype, albeit still with limited functionality.

Our studio 3DIS4U, 3D Image Studio for Uppsala, is used for our seminars, some classes, and for external events. Our current projects are visualized on our "CBA TV", in the form of very short "trailers" on a LCD monitor facing the main entrance stairway where students and colleagues from other groups can get a glimpse of our most current research.

We organized the national Swedish conference on image analysis, SSBA in March with 100 participants and we were also involved in the organization of seven other conferences, ranging from area co-chairing the world conference ICPR to hosting collaborative workshops with our international partners.

We are very active in international and national societies. Ingela Nyström served as second vice-president of the International Association of Pattern Recognition (IAPR) and was in September elected secretary of IAPR. Gunilla Borgefors was Area Editor for Pattern Recognition Letters and is now appointed Editor in Chief. Researchers at CBA also served on several other journal editorial boards, scientific organization boards, and conference committees. We were involved in half a dozen PhD dissertation committees, nationally and internationally. And we took a very active part in reviewing grant applications and scientific papers submitted to conferences and journals. Ewert Bengtsson served as chair of the Evaluation Panel for Medical Engineering for the Swedish Research Council and on a panel for evaluating advanced research proposals for the European Research Council. Locally he serves as senior advisor to the Rector of UU on information technology and also as Chair of the University IT-council, and holds many other related appointments.

Since 1993/94, CBA assembles extensive annual reports, such as this document, that describes in some detail what we achieved during the year. These annual reports are intended for anyone interested in our work. Note that each section in this report starts with a short summary printed in a larger font than the following detailed material.

Our annual reports have been available on the Internet since 1998. For this issue, see
http://www.cb.uu.se/verksamhet/annual_report/AR10html/

1.2 Summary of research

The objective of CBA is to carry out research and education in computerized image analysis and perceptualization, both within image processing as such and with the goal of developing better methods, algorithms and systems for applications primarily within biomedicine and forestry.

We are pursuing this objective through a large number of research projects, ranging from fundamental mathematical methods development to application-tailored developments and testing, the latter mainly in biomedicine and forestry. We are also developing new methods for perceptualization, combining computer graphics, haptics and image processing in new ways.

Our research is organized in a large number of projects (54) of varying size, ranging in effort from a few person months to several person years. There is a lot of interaction between different researchers; generally a person is involved in several different projects in different constellations with internal and external partners. In this context, the university affiliation of the particular researchers seldom is of importance.

On the theoretical side, most of our work is based on discrete mathematics with fundamental work on skeletons, distances and tessellations in three and more dimensions. Another fruitful theoretical foundation is fuzzy methods.

Several projects deal with light microscopy, developing tools for modern quantitative biology and clinical cancer detection and grading. We are collaborating with local biologists and pathologists as well as with research centers in the US and India, and a Danish company.

We also work with electron microscopy (EM) images; one application is focused on finding viruses in EM images. Here the vast search area and the small size of the target structures create great challenges. We are also developing methods for studying the 3D shape of large molecules based on electron

tomography. This work was presented in a PhD thesis this year.

Another imaging modality, providing 3D images of small structure, is X-ray micro-tomography. We are developing methods to use such images to study the internal structure of paper and composites, trabecular bone, and of bone-implant integration.

On a macroscopic scale we are working with interactive segmentation of 3D CT and MR images. We have developed a segmentation toolbox, WISH, which is publicly available. Part of this work also involves haptic interaction, and we have started a large interdisciplinary project aiming at a new generation haptic system, a glove with which a user can feel and manipulate virtual objects in the same manner in which he/she would manipulate a real object.

Results from our project most clearly related to forestry, the estimation of timber quality from cameras mounted under harsh conditions in saw mills, was presented in a PhD thesis this year.

Please, see Section 5 for details on our interesting research projects.

Another activity bridging over between research and education is supervision of master thesis projects. This year we completed a dozen such projects. In Section 3.2, we describe these theses.

1.3 How to contact CBA

CBA maintains a home page on the World Wide Web (WWW) both in English and in Swedish. The main structure contains links to a brief presentation, staff, vacant positions (if any), etc. It also contains information on courses, seminars (*Note* that our Monday 14:15 seminar series is open to anyone interested), a layman introduction to image analysis, this annual report (as .html and .pdf versions), lists of all publications since CBA was created in 1988, and other material.

CBA home-page: http://www.cb.uu.se/

In addition to the CBA home page, all personnel have their own home pages, which are linked to the CBA "Staff" page. On these, you can usually find detailed course and project information and other interesting things.

Centre for Image Analysis (Centrum för bildanalys, CBA) can be contacted in the following ways:

Visiting address:	Lägerhyddsvägen 2 Polacksbacken, building 2, south entrance, floor 1 Uppsala
Postal address:	Box 337 SE-751 05 Uppsala Sweden
Telephone:	+46 18 471 3460
Fax:	+46 18 553447
E-mail:	cb@cb.uu.se

2 Organization

CBA is a joint entity belonging equally to Uppsala University (UU) and Swedish University of Agricultural Sciences (SLU), but administered through UU. Over the years the number of people working at CBA has varied considerably. We have now come back to the levels from 10 years ago with about 39 people working at CBA. About 60% are employed by UU, the other 40% by SLU. The activity at CBA is similar to any department within a single university, but the administration becomes more complicated due to our close relation to two different universities. Our total turnover for 2010 was 20.6 million SEK. Roughly speaking UU, SLU and external grants each provide one third of our income. For 2010 the proportions were more exactly: 34% from UU, 25% from SLU, and 41% from external sources.

2.1 Constitution

The CBA was founded in 1988 and was until the end of 2010 an independent entity within the Faculty of Science and Technology (TN-Faculty) at UU and within the Faculty of Forest Sciences (S-Faculty) at SLU, respectively. The economy was managed as one unit within UU while each one of us was employed at one of the two universities. CBA was managed by a board and a director, the latter having the executive power. After an administrative review of all centers at UU in 2005 there were some minor changes proposed for the CBA constitution. This new constitution was never formally adopted and there was a delay in appointing a new board when the mandate for the previous board ended in the end of 2006. In the meantime the management of CBA rested solely with the director Ewert Bengtsson. Ingela Nyström took over the role as Deputy Director from Olle Eriksson during 2010. As advisors to the director, we had an informal management group consisting of the academic personnel with permanent positions plus our administrator.

In early 2010, we finally got a new board with representatives from both universities. Just in time for its first meeting in May 2010 we also got the news that CBA was to be reorganized completely. During the rest of the year there were many discussions about the new organization in board meetings and other fora. The board proposed that there should be more thorough evaluations of organizational options and that decisions should wait until after the scientific evaluations that are to take place in the spring of 2011. The final decision by the faculty boards was, however, a new organization from the start of 2011. So from January 1, 2011, the UU part of CBA is a division within the Dept. of Information Technology. The formal status of the SLU part has not yet been decided. So the constitution is currently somewhat unclear. But all involved parties have stated that the intention is that CBA in effect should continue as a joint entity but with a more complex administrative structure.

At present the board members are:

- Jan-Erik Hällgren, chairman, S-Faculty, SLU
- Johan Fransson, S-Faculty, SLU
- Lena Holm, deputy, Faculty of Veterinary Medicine and Animal Science, SLU
- Per Lötstedt, TN-Faculty, UU
- Bengt Långström, deputy, TN-Faculty, UU
- Elna-Marie Larsson, Faculty of Medicine, UU
- Milan Gavrilovic, PhD student representative

2.2 Finances

CBA is financed through the two universities and through research grants and contracts. A small part of the personnel expenses are covered by undergraduate education at UU, mostly by the PhD students of both universities, who teach 10–20% of their time. (The UU Lecturers' teaching appointments are not included in our finances.)

The summary in Table1 describes our overall economy for 2010. Since part of our economy is handled at UU and part at SLU, this summary is based on joining the two accounts and clearing internal transactions between the universities. The numbers are rounded to the nearest 1000 SEK. The total cost is thus 18.7 MSEK for 2010, up 0.6 million from 18.1 MSEK for 2009. The total income was 20.6 MSEK.

The same numbers for income and costs are also given as pie charts in Figure 1. Which projects that are financed by whom can be ascertained in Section 5, where each project is listed. Project grants which have been received but not used are directly balanced to next year and are thus not included in the income-cost tables.

Table 1: CBA income and costs for 2010 in kSEK.

Income		**Costs**	
UU	6543	Personnel	11949
SLU	5159	Equipment	596
UU rent	500	Operating exp. 4)	2395
Governmental grants 1)	4575	Rent	1494
Non-governmental grants 2)	2850	University overhead	2268
Contracts 3)	944		
Financial netto	28		
Total income	**20599**	**Total cost**	**18702**

1) The Swedish Research Council, SIDA, Formas

2) Research foundations, EU

3) Internal invoices and compensations

4) Including travel and conferences

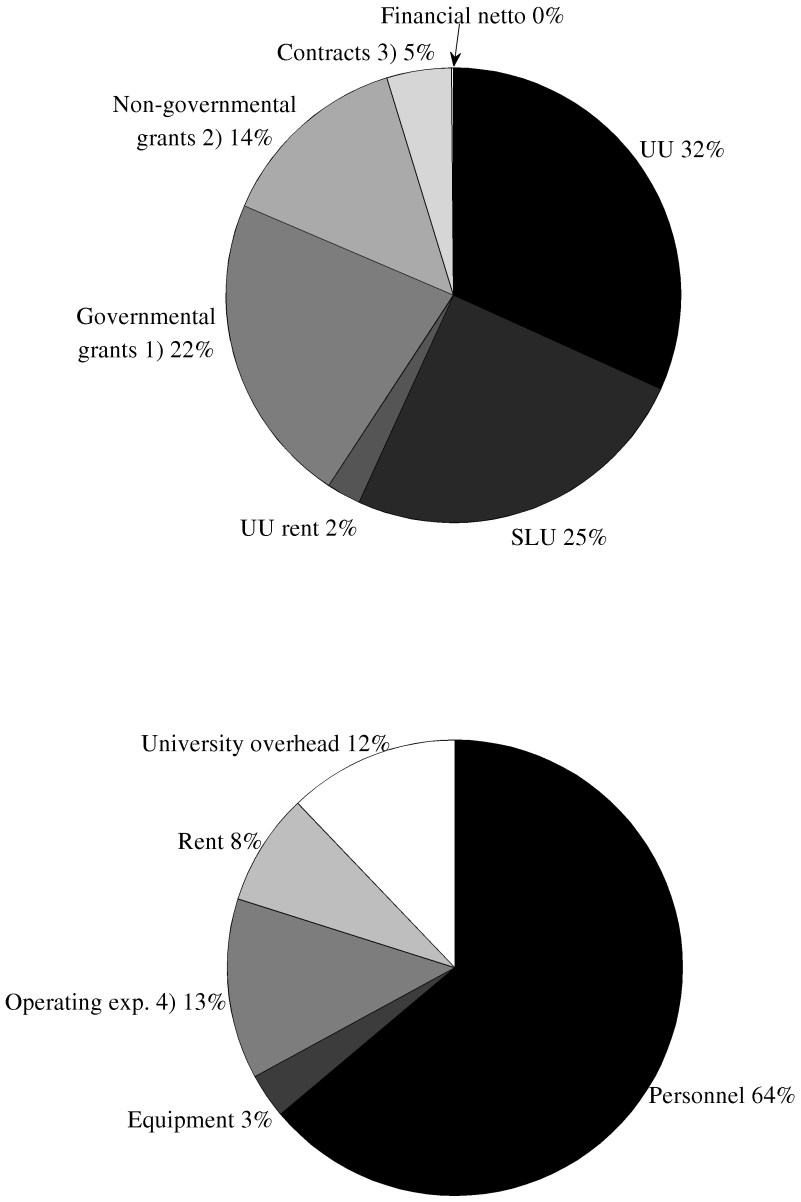


Figure 1: CBA income (top) and costs (below) for 2010.

2.3 Staff

Amin Allalou, Graduate Student, UU
Jimmy Azar, Graduate Student, 100701–, UU
Ewert Bengtsson, Professor, PhD, Director, UU
Gunilla Borgefors, Professor, PhD, SLU, UU
Anders Brun, Researcher, PhD, SLU
Ingrid Carlbom, Professor, PhD, UU
Hyun-Ju Choi, Researcher, PhD, –100531, UU
Vladimir Curic, Graduate Student, UU
Martin Ericsson, Research Engineer, –100630, UU
Olle Eriksson, Lecturer, PhD, (part time) UU
Azadeh Fakhrzadeh, Graduate Student, 100815–, SLU
Milan Gavrilovic, Graduate Student, UU
Magnus Gedda, Graduate Student, –100431, UU
Anders Hast, Researcher, PhD, (part time) UU
Gustaf Kylberg, Graduate Student, UU
Andreas Kårsnäs, Industrial Graduate Student, (part time) UU and Visiopharm, Hørsholm, Denmark
Joakim Lindblad, Researcher, PhD, (part time) SLU
Tommy Lindell, Docent, PhD, (part time) UU
Elisabeth Linnér, Graduate Student, 100517–, UU
Cris Luengo, Researcher, PhD, SLU
Patrik Malm, Graduate Student, UU
Filip Malmberg, Graduate Student, UU
Khalid Niazi, Graduate Student, UU
Bo Nordin, Researcher/Lecturer, PhD, (part time) UU
Kristin Norell, Graduate Student, –100631, SLU
Ingela Nyström, Docent, PhD, Deputy Director, (part time) UU
Fredrik Nysjö, Research Engineer, 100920–, UU
Pontus Olsson, Graduate Student, 100427–, UU
Hamid Sarve, Graduate Student, SLU
Stefan Seipel, Professor, PhD, (part time) UU and University of Gävle
Bettina Selig, Graduate Student, SLU
Ida-Maria Sintorn, Researcher, PhD, SLU
Robin Strand, Researcher, PhD, UU
Lennart Svensson, Graduate Student, SLU
Stina Svensson, Docent, PhD, (part time) SLU
Lena Wadelius, Administration
Erik Wernersson, Graduate Student, SLU
Carolina Wählby, Docent, Researcher, PhD, (part time) UU
Catherine Östlund, Researcher, (part time) SLU

Master Thesis students:
J. Björk, A. Dånmark, S. Goméz, U. Hammarqvist, J. Heidrich, K. Hubble, F. Nysjö, D. Skog

In addition to the above Graduate Students, G. Borgefors was supervisor to
Anders Larsolle, Dept. of Biometry and Engineering, SLU

The letters after the name indicate the employer for each person:
UU — Uppsala University
SLU — Swedish University of Agricultural Sciences
The e-mail address of the staff is `Firstname.Lastname@cb.uu.se`

3 Undergraduate education

Staff from CBA organizes and participates in many undergraduate courses at UU, even though we are not officially the unit responsible for them. We organize and teach the courses in image analysis and computer graphics, but we also teach other courses, such as programming (in C++ and Java) and mathematics.

We offer a number of Master thesis projects (examensarbeten) each year. Ten were completed during 2010.

3.1 UU courses

1. **Automatic Control I, 7.5 hp**
   Hamid Sarve
   Period: 100115–100322
2. **Computer Programming I, 5 hp**
   Erik Wernersson
   Period: 100118–100318
3. **Computer Graphics, 10 hp**
   Filip Malmberg
   Period: 100121–100305
4. **Computer Assisted Image Analysis I, 7.5 hp**
   Amin Allalou, Patrik Malm, Gustaf Kylberg, Milan Gavrilovic
   Period: 100319–100525
5. **Scientific Computing III, 5 hp**
   Elisabeth Linnér
   Period: 100830–101015
6. **Programming Bridging Course, 10 hp**
   Olle Eriksson, Lennart Svensson
   Period: 100830–101217
7. **Scientific Visualization, 5 hp**
   Filip Malmberg, Stefan Seipel, Pontus Olsson, Gustaf Kylberg, Patrik Malm
   Period: 100901–101012
8. **Computer Assisted Image Analysis II, 10 hp**
   Cris Luengo, Anders Brun, Vladimir Curic, Joakim Lindblad, Ida-Maria Sintorn, Robin Strand, Patrik Malm, Gustaf Kylberg
   Period: 101026–110113
9. **Medical Informatics, 5 hp**
   Ewert Bengtsson
   Period: 101111–101111
10. **Color Theory and Application - Perceptual and Design Issues, 1 hp**
    Stefan Seipel
    Period: 100217–100217
    Comment: External one day intensive course developed and given for system developers and designers at Banverket.

3.2 Master theses

1. **Visualization of Military Camp Sites**
   Student: Fredrik Olsson
   Supervisors: Björn Brundin
   Subject supervisor: Ingela Nyström
   Publisher: CBA Master Thesis No. 114 / UPTEC F10 022
   Comment: Only available from SAAB Aerotech
   Abstract: The purpose with this Master thesis project was to develop a tool, where 3D objects that can be found in military camps are created. These objects should be assembled to a 3D model of a camp. A prototype has been implemented that can be used for evaluation of how useful a 3D visualization of a military camp is and what benefits it can obtain compared to a 2D sketch. The 3D visualizations are created in SketchUp and functionality is in priority in front of graphical details. In addition, SketchUp is used as a tool when planning new military camps, so it is necessary that all objects can be deleted and moved and it should also be possible to add new objects to the camp. A Matlab function was written to read 2D maps and project them to a 3D map so the terrain can be imported to the SketchUp model. One prerequisite of the project is that the program should work on a quite ordinary laptop. Hence, in order to save memory space and computational times, the objects created are as small as possible (regarding bytes), without losing too much detail. A number of example camps are shown with various objects such as tents, vehicles, and roads.

2. **Synthetic 3D Pap Smear Nucleus Generation**
   Student: Sandra Gomez
   Supervisor: Patrik Malm
   Subject supervisor: Patrik Malm
   Publisher: CBA Master Thesis No. 115
   Abstract: In this project we present a 3D Pap smear cell nucleus generator. The shape and the texture are the important features for a realistic synthetic nucleus. For the first one, the shape, a deformed distance transform is used in order to generate deformed spheres. For the second one, the texture, a pseudo random noise algorithm, Perlin noise, is applied to the shape in order to generate the most realistic texture of a cell. As a result, we obtain synthetic 3D cell nuclei as they appear in Pap smear tests.

3. **Vad är viktigast i staden?**
   Student: Erik Almlöf
   Supervisors: Mats Dunkars
   Subject supervisor: Ewert Bentsson
   Publisher: CBA Master Thesis No. 116 / UPTEC STS 10 026
   Abstract: This paper is part of the research programme ViSuCity, a programme with the goal of creating more sustainable urban planning through the development of better visual tools, which ultimately means better communication between various parties of public planning. The paper concerns the implementation of MCE into a 3D program for visualization. Multi criteria evaluation (MCE) is a technique that has been developed during the last 20 years. It merges GIS with AHP, forming a decision making tool for localization of, for example, new buildings. The result is an automated tool that enables advanced analysis of geographic areas. The tool has a very high potential due to the completely automated MCE and it is adapted for people without a technical background, let alone formal training in MCE. It provides great opportunities to test different scenarios, something that should be an important advantage. The incorporation of MCE into 3D models has made it easier for users to relate the maps to reality, since a detailed 3D model is very easily understood in terms of geographical placement. A brand new feature that has not previously been used is the ability to import new objects and give feedback to the analysis. A summary of research on the MCE underlines the current situation, that relatively little research exists surrounding the use and demand of MCE. This paper unfortunately contributes to this fact since no user studies have been done due to lack of time. This is something future research should focus on.

4. **Nuclei Segmentation on Bright-Field Images**
   Student: Fernandez, Francisco Cruz
   Supervisor: Amin Allalou
   Subject supervisor: Amin Allalou
   Publisher: CBA Master Thesis No. 117/UPTEC IT 10 027

Abstract: Nuclei segmentation is a common and complicated task in image analysis. There is no general solution for the problem, and depending on the image characteristics the segmentation can be performed in different ways. Bright-field images add some complications to the problem; the color of some elements of the image is close to the color of the nuclei, making the segmentation difficult. In this thesis some methods are presented to complete this task, two classifiers, minimum distance classifier and multilayer perception are tested to enhance the nuclei. After the classification, threshold methods together with morphological operations are used to get the segmentation of the nuclei with an accuracy around 85%.

5. **Implementation of 3D Imaging for Two-photon Laser Scanning Microscopy**
   Student: Chetan Nagaraja
   Supervisor: Klas Kullander, Dept. of Neuroscience, UU
   Subject supervisor: Robin Strand
   Publisher: CBA Master Thesis No. 118 / UPTEC IT 10 031
   Abstract: Information exchange between neural systems occurs at the level of populations of neurons. Thus in order to understand how this information exchange occurs, it is indispensable to understand the role of underlying neuronal systems.

   Electrophysiological techniques have enhanced our understanding of the nervous system by enabling the study of properties of single ion channels to that of ensembles of neurons. While electrophysiological measurements offer excellent temporal resolution, high sensitivity and a good SNR as they are in direct physical contact with the cells under study, they lack spatial resolution as this method provides a readout of the electrical signals from single or ensembles of neurons in the vicinity of the electrodes (Scanziani et al, 2009).

   Imaging techniques have gained a lot of prominence because they are non-invasive and provides excellent spatial resolution (Scanziani et al, 2009). The advent of fluorescent genetically encoded optical probes and other fluorescent synthetic indicators has enabled the study of network functions of neurons (Handel et al, 2008).

   There are various imaging techniques but the one most suited to study network activity is Multiphoton emission (MPE) microscopy because of its ability to image at greater depths in the tissue. In particular, the most popular and extensively used method in this class is the 2-Photon Microscopy. This has provided the ability to study activity patterns of neuronal ensembles at greater depths and the phototoxicity associated with one photon emission is greatly reduced (Potter, 1996).

   Imaging methods until recently have employed 2D scanning at planes normal to the light axis. It is known that processing of information occurs at local ensembles of neurons , hence obtaining population activity in a volume of interest is of greater relevance. This has been possible with the technological advancements over the past couple of years (Gobel et al, 2007).

   The aim of this thesis is to implement a fast 3D scanning algorithm using 2-photon microscopy to measure the activity patterns of neuronal ensembles. Further, this technique could be used in order to relate the activity of neurons with the behavioral output.

6. **Analysis Application for H.264 Video Encoding**
   Student: Ying Wang
   Supervisors: Zhuangfei Wu and Clinton Priddle
   Subject supervisor: Cris Luengo
   Publisher: CBA Master Thesis No. 119 / UPTEC IT 10 061
   Abstract: A video analysis application ERANA264(Ericsson Research h.264 video ANalysis Application) is developed in this project. Erana264 is a tool that analyzes H.264 encoded video bitstreams, extracts the encoding information and parameters, analyzes them in different stages and displays the results in a user friendly way. The intention is that such an application would be used during development and testing of video codecs. The work is implemented on top of existing H.264 encoder/decoder source code (C/C++) developed at Ericsson Research.
   Erana264 consists of three layers. The first layer is the H.264 decoder previously developed in Ericsson Research. By using the decoder APIs, the information is extracted from the bitstream and is sent to the higher layers. The second layer visualizes the different decoding stages, uses overlay to display some macro block and picture level information and provides a set of play back functions. The third layer analyzes and presents the statistics of prominent parameters in video compression process, such as video quality measurements, motion vector distribution, picture bit distribution etc.

7. **Underwater 3D Surface Scanning using Structured Light**
   Student: Nils Törnblom
   Supervisor: David Stenman, WesDyne TRC AB, Täby
   Subject supervisor: Cris Luengo
   Publisher: CBA Master Thesis No. 120 / UPTEC F 10 063
   Abstract: In this thesis project, an underwater 3D scanner based on structured light has been constructed and developed. Two other scanners, based on stereoscopy and a line-swept laser, were also tested. The target application is to examine objects inside the water filled reactor vessel of nuclear power plants. Structured light systems (SLS) use a projector to illuminate the surface of the scanned object, and a camera to capture the surfaces' reflection. By projecting a series of specific line-patterns, the pixel columns of the digital projector can be identified off the scanned surface. 3D points can then be triangulated using ray-plane intersection. These points form the basis the final 3D model.
   To construct an accurate 3D model of the scanned surface, both the projector and the camera need to be calibrated. In the implemented 3D scanner, this was done using the Camera Calibration Toolbox for Matlab. The codebase of this scanner comes from the Matlab implementation by Lanman & Taubin at Brown University. The code has been modified and extended to meet the needs of this project. An examination of the effects of the underwater environment has been performed, both theoretically and experimentally. The performance of the scanner has been analyzed, and different 3D model visualization methods have been tested.
   In the constructed scanner, a small pico projector was used together with a high pixel count DSLR camera. Because these are both consumer level products, the cost of this system is just a fraction of commercial counterparts, which uses professional components. Yet, thanks to the use of a high pixel count camera, the measurement resolution of the scanner is comparable to the high-end of industrial structured light scanners.

8. **Evaluation of a Holographic 3D Display**
   Student: Jim Björk
   Supervisors: Robin Strand, Ingrid Carlbom
   Subject supervisor: Stefan Seipel
   Publisher: CBA Master Thesis No. 121 / UPTEC F 10 064
   Abstract: An autostereoscopic display based on a Holographic Optical Element (HOE) presents new opportunities for faithful 3D displaying but also presents potential new problems, such as: accuracy of 3D objects, interactivity and user perception. In this evaluation, which is the first of its kind for this type of display, I have explored and tested methods and tools for the evaluation of these potential problems. I have found that the visual quality is comparable to more common display types but with a significant visual delay due to the parallel rendering of graphics and the projectors significant input lag. From this I have concluded that the display system is not yet ready for its intended purpose, cranio-maxillofacial surgery planning. We need projectors with less input lag and preferably better optics. The software needs to be optimized for multimonitor rendering as well.

9. **Gait-based Reidentification of People in Urban Surveillance Video**
   Student: Daniel Skog
   Supervisor: Cris Luengo
   Subject supervisor: Robin Strand
   Publisher: CBA Master Thesis No. 122 / UPTEC IT 10 040
   Abstract: Video surveillance of large urban areas demands the use of multiple cameras. consider tracking a person moving between cameras in such a system. When the person disappears from the view of one camera and then reappears in another, the surveillance system should be able to determine that the person has been seen before and continue tracking. The process of determining this connection is known as reidentification.

   Gait is a biometric that has been shown to be useful in determining the identities of people. It is also useful for reidentification as it is not affected by varying lighting conditions between cameras. Also, it is hard for people to alter the way they are walking without it looking unnatural.

   This project explores how gait can be used for reidentification. To investigate this, a number of different gait–based methods used for identification of people were used for reidentification. The methods are based on the active energy image, gait energy image, frame difference energy image, contours of silhouettes, and the self–similarity plot. The Fourier transform of the gait silhouette volume will also be tested. These methods are appearance based and the common theme is that a sequence of silhouettes of the subject is

transformed into a representation of the gait. The representations are then used for reidentification by comparing them to other gaits in a pool using a simple classification method based on the nearest neighbor classifier.

Two datasets were used to test the methods. The first dataset was captured with live surveillance cameras in an urban scene and the second using a home video camera. The lower quality of the footage in the first dataset affected the results, obtaining only about 34% correct reidentifications. This can be compared with the higher quality dataset which gave a result of about 80% correct reidentifications.

10. **Image Processing to Detect Worms**
Student: Javier Fernández
Supervisor: Johan Henriksson (KI)
Subject supervisor: Anders Brun
Examiner: Anders Jansson
Partner: Karolinska Institutet
Publisher: CBA Master Thesis No. 123 / UPTEC IT 10 045
Abstract: The nematode C. elegans is a widely used model organism. It has many cells with human equivalents, making it possible to study pathways conserved in humans and related conditions. Being small and transparent, it also lends itself well to a variety of high-throughput screening techniques. Worm identification should be as automated as possible since it is too labor-intense and time-consuming to do it manually.

    Here we present an image processing methodology to detect C. elegans in high-throughput microscope images. The provided semi-automatic solution makes it possible to effectively identify individual worms in worm clusters. In general terms, the process is as follows: A given image is segmented, thus separating groups of worms from the background. Individual worms are detected automatically, following a worm-shape matching process. For worm clusters, the matching process is based on finding feasible worm shapes by minimizing the distance between the cluster and generic worm shapes, which are deformed to fit it. Wrong and missing conformations can be quickly fixed manually.

    The provided methodology is a novel approach to successfully detect individual C. elegans worms in high-throughput microscope images. Results show that this semi-automatic solution makes it possible to fit the shape of 100% of worms in the image, unlike previous automated methods that reach, at most, less than 90% in average, for similar test sets. The detection process is usually achieved in less than half a minute for difficult images. For easier images, the total match can often be calculated in a fully automatic way. Time cost and matching accuracy are considerably improved with respect to manual identification.

    The solution was implemented in Java and adjusted to Endrov, which is an open source plug-in architecture for image analysis, and is to be used at the Dept. of Bioscience and Nutrition, Karolinska Institute, Sweden.

11. **Digital Straight Line Segment Recognition on Non-Standard Point Lattices**
Student: Kelly Hubble
Supervisor: Robin Strand
Subject supervisor: Andreas Strömbergsson, Dept. of Mathematics, UU
Publisher: U.U.D.M. project report; 2010:1
Abstract: OC-DSSr is a digital straight line segment (DSS) recognition method in 3D non-Cartesian point lattices. A brief overview of image analysis is given, along with its relationship to digital geometry and non-Cartesian cubic lattices. The Body-Centered Cubic (BCC) and Face-Centered Cubic (FCC) lattices are reviewed. A digitization method-dependent definition of a DSS is used to develop OC-DSSr. The supercover digitization is used to digitize curves on non-Cartesian lattices. An extension to the supercover is proposed to achieve α-connectivity in non-Cartesian lattices. A new independent definition of a DSS is proposed, based on the presented recognition method.

12. **Development of an Image Processing Tool for Fluorescence Microscopy Analysis of Paper Chemistry**
Student: Åsa Nyflött
Supervisor: Lars Johansson, Karlstad University, Gunilla Carlsson, Karlstad University, Carl-Henrik Ljungqvist, Stora Enso, Anders Brun
Examiner: Kjell Magnusson, Karlstad University
Partners: Karlstads Universitet, Stora Enso
Publisher: Karlstads Universitet
Abstract: Paper making today is, to some extent, based on empirical knowledge. It is well known that

fines, pH, charge and ion strength affect the manufacture of paper. One way of extending knowledge of the mechanisms of paper chemistry is to follow the trajectories of fines and additives in the paper suspension to gather information as to the manner in which they react. Four tracking algorithms adapted to the needs of this particular problem were implemented in order to track particles efficiently. The tracking algorithms include two variants of the well-known Lucas-Kanade algorithm and template matching techniques based on cross-correlation and least squares matching. Although these techniques are similar in principle, the actual tracking can nevertheless differ; the Lucas-Kanade algorithms were found to be more invariant to noise, whereas the cross- correlation and least squares methods are more rapid to execute in Matlab. The tracking methods have been evaluated using a simulator to generate image sequences of synthetic particles moving according to Brownian motion. Tracking has also been evaluated on microscope images of real latex particles where the results have been compared to manual tracking. Tracking of both the simulated particles and the latex particles resulted in similar results when compared to known position and manual tracking, respectively.

The developed simulator was used to evaluate the tracking algorithms and it can also be used to predict a real system if it can be expressed mathematically.

4 Graduate education

We had as many as three PhD exams in 2010, where the supervision came from CBA staff. Two of them were by PhD students belonging to CBA, while one was from the Dept. of Agriculture, SLU.

We gave three PhD courses of interest to our own students that also enticed external students. At the end of 2010, we were main supervisors for 16 PhD students, eleven at UU and five at SLU.

4.1 Graduate courses

1. **Research Methodology for Image Analysis, 4 hp**
   Gunilla Borgefors, Ewert Bengtsson
   Period: 091124–100120
   Comment: This course is intended for PhD students who started their research career recently. The goal is to give general and useful knowledge about how to become a good and published researcher in image analysis and/or various applications thereof. Ingrid Ogenhall, Ångström library gave one lecture.

2. **Fuzzy Sets and Fuzzy Techniques, 7.5 hp**
   Joakim Lindblad, Nataša Sladoje, Milan Gavrilovic
   Period: 100215–100326
   Description: This course provides the foundations of fuzzy set theory and fuzzy reasoning, as well as practical hands on experience of fuzzy techniques in various applications through computer exercises and project work.

3. **Linear Methods in Multidimensional Signal Analysis, 4.5 hp**
   Anders Brun, Klas Nordberg, Rudolf Mester, Leif Haglund, Björn Svensson, Magnus Herberhsson
   Period: 100810–100813
   Comment: The course is given as SSBA Summer School 2010. Cris Luengo and Robin Strand participated in the planning of the course.

4.2 Dissertations

1. *Date:* 100520
   Contributions to 3D Image Analysis using Discrete Methods and Fuzzy Techniques: With Focus on Images from Cryo-Electron Tomography
   Student: Magnus Gedda
   Supervisor: Stina Svensson
   Assistant Supervisors: Ewert Bengtsson; Carolina Wählby
   Opponent: Punam Saha, Dept. of Electrical and Computer Engineering, The University of Iowa, Iowa City, USA
   Committee: Martin Rydmark, Göteborgs University, Michael Felsberg, Linköpings University, Ingela Nystöm, CBA, Lars Norlen, Karolinska Institutet, Nataša Sladoje, University of Novi Sad, Serbia.
   Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-7768-4
   Abstract: With the emergence of new imaging techniques, researchers are always eager to push the boundaries by examining objects either smaller or further away than what was previously possible. The development of image analysis techniques has greatly helped to introduce objectivity and coherence in measurements and decision making. It has become an essential tool for facilitating both large-scale quantitative studies and qualitative research. In this Thesis, methods were developed for analysis of low-resolution (in respect to the size of the imaged objects) three-dimensional (3D) images with low signal-to-noise ratios (SNR) applied to images from cryo-electron tomography (cryo-ET) and fluorescence microscopy (FM). The main focus is on methods of low complexity, that take into account both grey-level and shape information, to facilitate large-scale studies. Methods were developed to localise and represent complex macromolecules in images from cryo-ET. The methods were applied to Immunoglobulin G (IgG) antibodies and MET proteins. The low resolution and low SNR required that grey-level information was utilised to create

fuzzy representations of the macromolecules. To extract structural properties, a method was developed to use grey-level-based distance measures to facilitate decomposition of the fuzzy representations into subdomains. The structural properties of the MET protein were analysed by developing a analytical curve representation of its stalk. To facilitate large-scale analysis of structural properties of nerve cells, a method for tracing neurites in FM images using local path-finding was developed. Both theoretical and implementational details of computationally heavy approaches were examined to keep the time complexity low in the developed methods. Grey-weighted distance definitions and various aspects of their implementations were examined in detail to form guidelines on which definition to use in which setting and which implementation is the fastest. Heuristics were developed to speed up computations when calculating grey-weighted distances between two points. The methods were evaluated on both real and synthetic data and the results show that the methods provide a step towards facilitating large-scale studies of images from both cryo-ET and FM.

2. *Date:* 100604
Automatic Analysis of Log end Face Images in the Sawmill Industry
Student: Kristin Norell
Supervisor: Gunilla Borgefors
Assistant Supervisors: Mats Nylinder, Dept. of Forest Products, SLU; Lars Björklund, SDC IT-company for the Swedish forestry sector
Opponent: Karl Entacher, Information Technology and Systems Management, Salzburg University, Austria
Committee: Gunnar Sparr, Dept. of Mathematics, Lund University; Björn Kruse, Dept. of Science and Technology, Linköping university; Anders Grönlund, Dept. of Wood Technology, Luleå University
Publisher: Acta Universitatis agriculturae Sueciae, ISBN: 978-91-576-7502-6
Abstract: At present grading of sawlogs in a sawmill relies on visual inspection wherein a human expert grades a log every few seconds as it passes on a conveyor belt. This tedious and difficult work is prone to substantial inter- and intra-grader variability.

This dissertation presents methods for automatic analysis of end faces from Scots pine (Pinus sylvestris L.) and Norway spruce (Picea abies (L.) Karst). Two features are extracted: the pith (centre core) position and the number of annual rings. The pith detection uses local orientations to estimate the centre of the annual rings in a manner that is robust to disturbances as knots and cracks as well as partial coverage of dirt or snow. The number of annual rings is counted using the polar distance transform, a tool developed here. This transform combines the image intensity and the circular shape of the rings so that the annual ring pattern can be outlined in rough and noisy images. First the marks on end faces from uneven sawing are removed using an automatic method developed in this work.

The data are images of untreated end faces mostly acquired at sawmills. A large amount of the data was imaged using a camera mounted above a conveyor belt at a sawmill, collecting images every month during one year. In total, the data consists of over 4000 images of pine and spruce. In this dissertation an algorithm for generating synthetic log end face images is also presented. The synthetic data can be used as a tool for developing image analysis methods.

The annual ring measurements were thoroughly evaluated on pine end face images acquired using the mounted end face camera. This evaluation shows that the method performs equally well as an experienced manual grader for grading the logs into quality classes. The method can thus be used as a component of an automatic grading system, overseen by a manual grader.

3. *Date:* 101203
Measuring and Modelling Parameters From Hyperspectral Sensors for Site-specific Crop Protection
Student: Anders Larsolle
Supervisor: Girma Gebresenbet, Prof. Dept of Energy and Technology, SLU
Assistant Supervisor: Gunilla Borgefors
Opponent: Oliver Hensel, Kassel University, Witzenhausen, Germany
Committee: Rainer Lenz, Dept. of Science and Technology, Linköping University Campus Norrköping
Anneli Lundkvist, Dept. of Crop Production Ecology, SLU, Uppsala
Jan-Erik Mattsson, Dept. of Agriculture–farming systems, technology and product quality, SLU Alnarp
Publisher: Faculty of Natural Resources and Agricultural Sciences, SLU, ISBN:978-91-576-7539-2
Abstract: This thesis sought to optimise systems for plant protection in precision agriculture through developing a field method for estimating crop status parameters from hyperspectral sensors, and an empirical

model for estimating the required herbicide dose in different parts of the field.

The hyperspectral reflectance measurements in the open field took the form of instantaneous spectra recording using an existing method called feature vector based analysis (FVBA), which was applied on disease severity. A new method called iterative normalisation based analysis (INBA) was developed and evaluated on disease severity and plant biomass. The methods revealed two different spectral signatures in both disease severity and plant density data. By concentrating the analysis on a 12% random subset of the hyperspectral field data, the unknown part of the data could be estimated with 94-97% coefficient of determination.

The empirical model for site-specific weed control combined a model for weed competition and a dose response model. Comparisons of site-specific and conventional uniform spraying using model simulations showed that site-specific spraying with the uniform recommended dose resulted in 64% herbicide saving. Comparison with a uniform dose with equal weed control effect resulted in 36% herbicide saving.

The methods developed in this thesis can be used to improve systems for site-specific plant protection in precision agriculture and to evaluate site-specific plant protection systems in relation to uniform spraying. Overall, this could be beneficial both for farm finances and for the environment.

4.3 Docent degrees

1. *Title:* Phongs Belysningsmodell – hur den förbättrats genom åren
   The Phong Illumination Model - How it has been Improved through the Years
   Anders Hast
   Date: 100209
   Abstract: The Classical illumination model presented by B.T. Phong in the early seventies have been the most widely used in the computer graphics area. It is both fast and simple since the idea is to produce a visually plausible result rather than one based on exact physics. More advanced illumination models are based on the behaviour of different materials and these become more and more popular but still the model by Phong is often used in scientific visualization, computer games and in the production of animated movies. The different parts of the model will be discussed together with important improvements and variants that have been done by others as well as by the presenter and his colleagues.
   Comment: The docent lecture was held in Swedish.

2. *Title:* Ugly Yet Informative vs. Fine-looking but Frozen Information - Which One Should be the Future of PET Imaging
   Pasha Razifar
   Date: 100915
   Abstract: Positron emission tomography (PET) is a non-invasive imaging modality and an excellent exploratory tool, based on “tracing” molecules labelled with a positron emitting radionuclide, called “tracer”. One of the main strengths of PET is its ability to depict and illustrate metabolic, physiological and biological interaction of the administered tracer with target(s) of interest in either a sector or whole body of a living creature, as image volumes.

   A decade ago this functional information provided by PET was coupled with excellent anatomical information provided by Computed Tomography (CT), introducing a new and powerful duo-modality intended to improve the diagnosis value and to fulfil the drawbacks of using two separate imaging modalities, especially in the field of Oncology. Furthermore, one of the revolutions and at the same time one of the ”curses” on PET when introducing this excellent duo-modality was, and still is, the frequent use of Fluorodeoxyglucose (FDG) when performing whole body static PET/CT. Due to short scanning time and good image quality this approach has become a golden standard tool for tumour imaging. However, when performing static imaging the fourth dimension, time, is frozen and this approach generates a ”univariate” image volume, which illustrates only the mean tracer distribution of the administered tracer during the scanning time. This deflates the key strength of the PET, the exploratory dimension, which is based on ”tracing a molecule labelled with a positron emitting radionuclide”. Moreover, static imaging requires a good knowledge about the kinetic behaviour, affinity and the specificity of the administered tracer which requisites many experiments and years of experience.

   On the other hand a dynamic PET imaging (where a sector is scanned sequentially during different time points called frames) generates sequential image volumes which have poorer image quality compared with

images obtained when performing static imaging. However, these sequential image volumes can be regarded as multivariate image volumes from which physiological, biochemical and functional information can be ”traced” and derived by analyzing the distribution and kinetics of the administrated radiolabelled molecules. This implies that each of the image volumes displays/contains part of a kinetic information representing physiological behaviour of the administered tracer during different time points (the 4-th dimension). Due to presence of the fourth dimension, dynamic image volumes could be quantified and analysed using several approaches/methods such as graphical modelling, parametric images, pixel-wise modelling, and multivariate image analysis.

The important question still remains: What are scientists looking for when they are utilizing an excellent imaging tool such as PET? Ugly yet informative or fine-looking but frozen information?
Comment: The docent lecture was held in English.

Docent degrees from CBA

1. Lennart Thurfjell, 1999
2. Ingela Nyström, 2002
3. Lucia Ballerini, 2006
4. Stina Svensson, 2007
5. Tomas Brandtberg, 2008
6. Hans Frimmel, 2008
7. Carolina Wählby, 2009
8. Anders Hast, 2010
9. Pasha Razifar, 2010

4.4 Doctoral conferment ceremonies

1. *Title:* Promotor for the Faculty of Forest Science, SLU
Gunilla Borgefors
Date: 101009
Description: The promotor confers the ceremony where those who have defended their PhD theses during the year receive their PhD diplomas and laurels or hats. The promotor each year is the most senior professor at the faculty that has not yet been promotor. There are a number of tasks apart from the actual conferment ceremony that was held in Latin, for the first time in the history of the Faculty.

Promotors at doctoral conferment ceremonies from CBA

1. Ewert Bengtsson, TN-Faculty, UU, 2009
2. Gunilla Borgefors, S-Faculty, SLU, 2010

5 Research

CBA is conducting a whole range of projects ranging from basic image analysis research to direct application work, and increasingly in scientific visualization. By keeping close touch both with theoretical front line research and with real life application projects, we believe that we make the best contribution to our field. On the theoretical side, we are especially strong in volume and multispectral image analysis. In line with the stated goal for CBA, we give priority to applications in the fields of biomedicine and the environmental sciences, including the forest industry; we are part of the Faculty of Forest Sciences at SLU.

In this Section, we list the 54 research projects that were active during 2010. Some are large projects that have been active for a long time, while others are smaller and short-lived. We started eleven new projects this year, while eight were completed since last year.

The list of projects is roughly grouped into image analysis theory; forest and agricultural projects; medical image applications (from proteins to organs); computer graphics and visualization; and finish with aquatic remote sensing and some miscellaneous projects. For each project, we list who at CBA is involved, where the funding comes from, when the project started (and finished), and who our cooperation partners outside CBA are.

As is obvious from the descriptions, most of the projects are carried out in close cooperation with researchers from other universities and from other research areas. In Section 5.7, we list the 42 international groups in 16 countries and 46 national groups with which we have had active cooperation in 2010.

5.1 Theory: Discrete Geometry, Volumes and Fuzzy Methods

1. **Geodesic Computations in Sampled Manifolds**
   Anders Brun
   Partners: Ola Nilsson, Dept. of Science and Technology, Linköping University, Martin Reimers, Centre of Mathematics for Applications, University of Oslo, Norway
   Funding: S-faculty, SLU
   Period: 0806–
   Abstract: The estimation of geodesic distances in sampled manifolds and surfaces, such as geometric mesh models in 3-D visualization or abstract sampled manifolds in image analysis, poses a difficult and computationally demanding problem. Despite the many advances in discrete mathematics and distance transforms, and fast marching and numerical methods for the solution of PDEs, the solution of the eikonal equation in a general manifold chart equipped with an arbitrary sampled metric known only in a discrete set of points has only recently beed adressed in 3-D and higher dimensions by researchers. In this project we focus on accurate computations of geodesic distances and related mappings, such as the log map, in 2-D and 3-D. Applications for such methods are found in computer graphics (e.g. camera movement, texture mapping, tensor field visualization) and basic image analysis (e.g. skeletonization, manifold learning, clustering).

2. **Comparison of Grey-Weighted Distance Measures**
   Magnus Gedda
   Funding: TN-faculty, UU
   Period: 0601–1005
   Abstract: In several application projects we have discovered the benefit of computing distances weighted by the grey levels traversed, e.g., Project 32. There are many ways of doing this, and in this project we have made a thorough comparison of the most popular distances calculated that take grey-level information into account; GRAYMAT, Distance On Curved Spaces (DOCS) and

the Weighted Distance On Curved Spaces (WDOCS). Already in 2006 we published a theoretical comparison describing the different aspects of the definitions.

3. **Distance Functions and Distance Transforms in Discrete Images**
   Robin Strand, Gunilla Borgefors
   Partner: Benedek Nagy, Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary
   Funding: TN-faculty, UU; S-faculty, SLU
   Period: 9309–
   Abstract: The distance between any two grid points in a grid is defined by a distance function. In this project, weighted distances have been considered for many years. A generalization of the weighted distances is obtained by using both weights and a *neighborhood sequence* to define the distance function. The neighborhood sequence (ns) allows the size of the neighborhood to vary along the paths. In a paper by Strand and Nagy that was presented at the Workshop on Applications of Discrete Geometry and Mathematical Morphology, weighted ns-distances are defined on the honeycomb grid, in which each voxel is a hexagonal prism.

4. **Skeletonization in 3D Discrete Binary Images**
   Robin Strand, Ingela Nyström, Gunilla Borgefors
   Partner: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Pozzuoli, Italy
   Funding: TN-faculty, UU; S-faculty, SLU
   Period: 9501–
   Abstract: Skeletonization is a way to reduce dimensionality of digital objects. A skeleton should have the following properties: topologically correct, centred within the object, thin, and fully reversible. In general, the skeleton cannot be both thin and fully reversible. We have been working on 3D skeletonization based on distance transforms for the last decade.
   By finding the set of centers of maximal balls (CMBs) and keeping these as anchor-points in the skeletonization process, the reversibility is guaranteed. In 2010, a paper by Strand on CMBs and some related concepts was accepted for the discrete geometry for computer imagery (DGCI) conference that will be held in Nancy in 2011.

5. **Image Processing and Analysis of 3D Images in the Face- and Body-Centered Cubic Grids**
   Robin Strand, Gunilla Borgefors
   Partner: Benedek Nagy, Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Debrecen, Hungary
   Funding: TN-faculty, UU; S-faculty, SLU
   Period: 0308–
   Abstract: The main goal of the project is to develop image analysis and processing methods for volume images digitized in non-standard 3D grids. Volume images are usually captured in one of two ways: either the object is sliced (mechanically or optically) and the slices put together into a volume or the image is computed from raw data, e.g., X-ray or magnetic tomography. In both cases, voxels are usually box-shaped, as the within slice resolution is higher than the between slice distance. Before applying image analysis algorithms, the images are usually interpolated to the cubic grid. However, the cubic grid might not be the best choice. In two dimensions, it has been demonstrated in many ways that the hexagonal grid is theoretically better than the square grid. The body-centered cubic (bcc) grid and the face-centered cubic (fcc) grid are the generalizations to 3D of the hexagonal grid. The fcc grid is a densest packing, meaning that the grid points are positioned in an optimally dense arrangement. The fcc and bcc grids are reciprocal, so the Fourier transform on an fcc grid results in a bcc grid. In some situations, the densest packing (fcc grid) is preferred in the frequency domain, resulting in a bcc grid in spatial domain. In some cases, the

densest packing is preferred in the spatial domain.

In 2010, results on sampling properties of the honeycomb point-lattice and the diamond grid were presented at International Conference on Pattern Recognition, Istanbul, Turkey. In Fig. 2, the ideal interpolation function on the honeycomb lattice is illustrated.

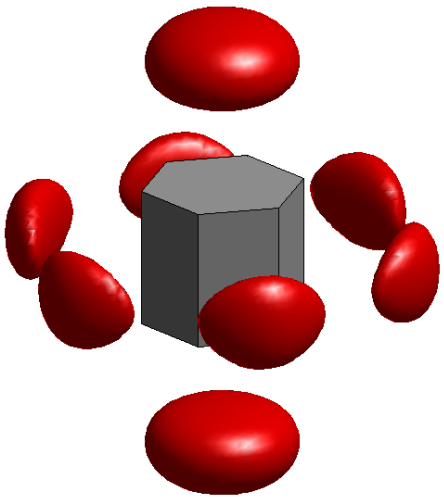


Figure 2: An isosurface of the ideal interpolation function on the honeycomb lattice is shown together with the Voronoi region of a grid point.

6. **Spel Coverage Representations**
   Joakim Lindblad, Vladimir Curic, Filip Malmberg
   Partners: Nataša Sladoje, Faculty of Technical Sciences, University of Novi Sad, Serbia; Attila Tanacs, Csaba Domokos, and Zoltan Kato, Dept. of Computer Science, Szeged University, Hungary
   Funding: S-faculty, SLU; Graduate School in Mathematics and Computing (FMB)
   Period: 0801–
   Abstract: This project concerns the study and development of partial pixel/voxel coverage models for image object representation, where spatial image elements (spels) are allowed fractional coverage by the object. The project involves both development of methods for estimation of partial spel coverage (coverage segmentation) as well as development of methods for properly utilizing the information contained in such segmented images (feature extraction). The project builds on previous experience and knowledge from more general fuzzy representations, where the restriction to coverage representations enables derivation of strong theoretical results.

   This theoretically founded project has strong ties with applications. Under 2010, results and knowledge from this project found use in Project 7 where it provided a good object representation for registration and matching tasks, as well as in the project "Estimation of Linear Shape Deformations and its Medical Applications" at the University of Szeged, Hungary, where coverage information is utilized for improved estimation of affine deformations of 3D objects. The latter work was presented at the International Conference on Image Processing (ICIP) in September 2010.

   In addition, further development of the theoretical framework related to coverage representations was undertaken during 2010. In close collaboration with Project 43 a framework for graph based coverage segmentations was developed. This work is presented in an article in Theoretical Computer Science, appearing in 2011.

7. **Set Distances and Their Application in Image Analysis**
   Vladimir Curic, Joakim Lindblad, Hamid Sarve, Gunilla Borgefors
   Partner: Nataša Sladoje, Faculty of Technical Sciences, University of Novi Sad, Serbia
   Funding: Graduate School in Mathematics and Computing (FMB)
   Period: 0908–
   Abstract: Methods for measuring distances between sets, which is a measure of how similar the sets are, can be useful for solving various image analysis related problems, such as registration, image retrieval and segmentation evaluation. Depending on how the distance measure is defined, it exhibits different properties, such as metricity, monotonicity, continuity, sensitivity to noise, complexity and speed of computation. It is therefore of interest to study and further develop different set distance measures, to be able to select appropriate distances for the different applications. An initial goal of this project is to evaluate existing and develop new set distances which are useful in image registration related problems. Of particular interest are properties of monotonicity and continuity.

   During 2010 we proposed new set distances between crisp sets of points and evaluated their usefulness for rigid body registration of binary images as well as their applicability for the real task of multi-modal 2D-3D registration of 2D histological sections of bone implant with corresponding 3D synchrotron radiation micro computed tomography (SRμCT) bone implant volumes. We extended proposed set distances for crisp sets to distances between fuzzy sets and observed the improved registration performance when utilizing fuzzy object representations, as compared to using a crisp object representation of the same resolution (see Fig. 3). This work is accepted to International Workshop on Combinatorial Image Analysis (IWCIA'2011).

   We intend to further extend this work within the framework of mathematical morphology towards more general methods for shape description and analysis. In addition, for the proposed set distances, we intend to perform a distance based classification of biomedical data.

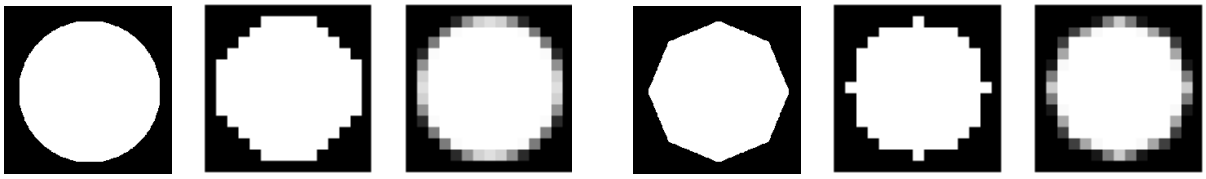


Figure 3: A: Continuous crisp disk, B: Crisp discrete representation of a continuous disk (obtained by Gauss centre point digitization), C: Fuzzy discrete representation of a continuous disk (obtained by coverage digitization), D: Continuous crisp octagon, E: Crisp discrete representation of a continuous octagon, F: Fuzzy discrete representation of a continuous octagon.

5.2 Forestry Related Applications

8. **Three-dimensional Paper Sheet Structure Analysis Based on Image Analysis**
   Catherine Östlund
   Partner: Innventia, Stockholm
   Funding: VINNMER programme, Swedish Governmental Agency for Innovation Systems
   Period: 0901–
   Abstract: Studies of paper sheet structure characterisation, e.g. the distribution of fibres, fibre flocs and the void areas between them, can be made using beta radiography or by splitting the paper in layers and study each layer, or by studying the cross-section of the paper. The three-dimensional (3D) structure of the sheet can from such data in some cases be estimated. The focus of this

research project is to propose 3D paper structure analysis methods based on image analysis, and to compare the results from two-dimensional analysis methods to those achieved with a 3D method. An X-ray microtomograph is used for studying 3D images.

9. **Image Analysis of the Internal Structure of Paper and Wood Fibre Based Composite Materials in 3D images**
Erik Wernersson, Anders Brun, Joakim Lindblad, Cris Luengo, Catherine Östlund, Gunilla Borgefors
Partners: Norwegian Pulp and Paper Research Institute, Trondheim, Norway; Innventia, Stockholm; Dept. of Fibre and Polymer Technology, Royal Institute of Technology, Stockholm; Dept. of Physics, University of Jyväskylä (UJ), Finland; SINTEF Materials and Chemistry, Norway; Risø National Laboratory, Technical University of Denmark, Faculty of Engineering, University of Novi Sad, Serbia
Funding: S-faculty, SLU; WoodWisdom-Net
Period: 0406–
Abstract: The internal structure of paper is important because many of its properties correspond directly to the properties of single fibres and their interaction in the fibre network. How single fibres in paper bond and how this affects paper quality is not fully understood, since most structure analysis of paper has been performed in cross-sectional, two-dimensional (2D) images whereas paper is a complex, three-dimensional (3D) structure, see Fig. 4.

Another application for wood fibres that has recently gained interest is wood polymer composite materials. The properties of these materials do not only depend on the structure of the fibre network, but also on the interaction between the fibres and the polymer matrix surrounding the fibres.

Advances in imaging technology have made it possible to acquire 3D images of paper and wood polymer composite materials. In this project, image analysis methods for characterizing the 3D material structure in such images are developed. The detailed knowledge of the material structure attainable with these methods is useful for improving material properties and for developing new materials.

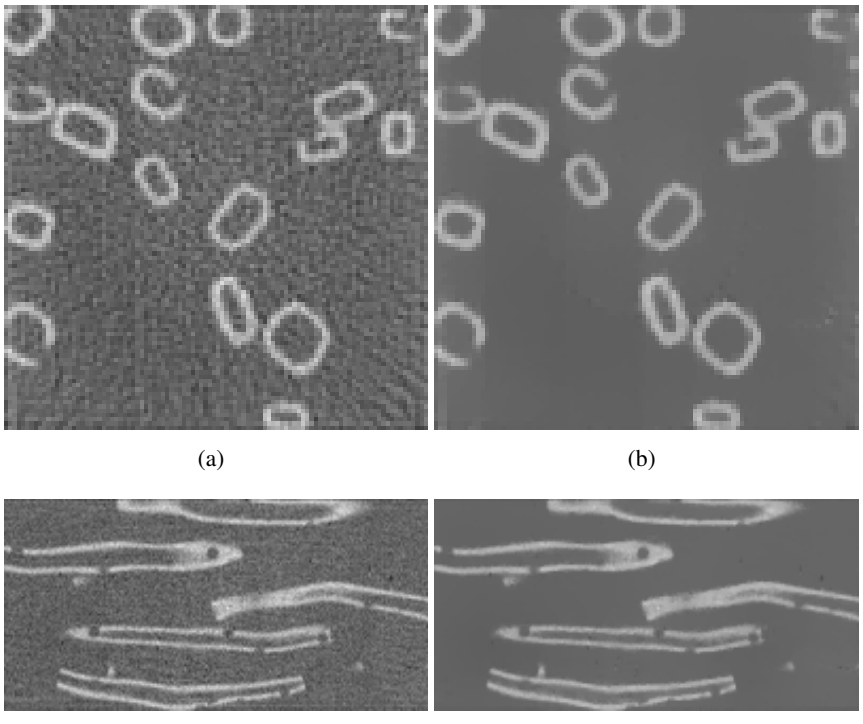
The project objective is to achieve a complete segmentation of individual fibres and pores in volume images of the material. Given such a segmentation, any desired measurement of the internal structure is available. Measurements on individual fibres and the structural arrangement of fibres can then be related to macroscopic material properties.

In this project, different volume images of paper and composite materials are available: one volume created from a series of 2D scanning electron microscopy (SEM) images at StoraEnso, Falun; and X-ray microtomography volume images of paper and composite samples imaged at the European Radiation Synchrotron Facility (ESRF) in Grenoble, France, at the Paul Scherrer Institut (PSI) in Villigen, Switzerland and during 2010 we have acquired several data with a tabletop scanner at University of Jyväskylä, Finland.

During 2010 further development of methods for de-noising of the acquired image volumes was undertaken. A variational approach, minimizing the image Total Variation by Spectral Conjugate Gradient optimization, showed to outperform previously used SUSAN filtering. The developed model for generating synthetic μCT data 10 facilitated objective performance comparison. Results of this study were presented at the International Conference on Pattern Recognition (ICPR) in August 2010 and some examples can be seen in Fig. 5

(a) (b)

Figure 4: (a) A slice from a binarised volume image of a composite material and (b) a surface rendering of a sample of a composite material.



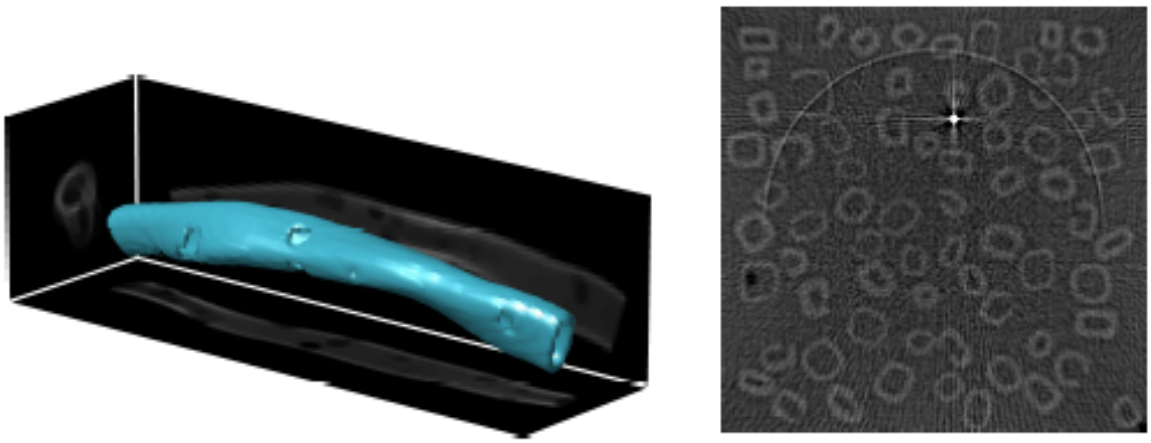
(a) (b)

(c) (d)

Figure 5: Left: Cross section of images with synthetic noise. Right: Noise removed by one of our methods where the image Total Variation is minimized by Spectral Conjugate Gradient optimization.

10. **Generation of Synthetic µCT Volumes**
    Erik Wernersson, Cris Luengo, Anders Brun, Catherine Östlund, Gunilla Borgefors
    Partners: Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway; Innventia, Stockholm; Dept. of Fibre and Polymer Technology, Royal Institute of Technology, Stockholm; Dept. of Physics, University of Jyväskylä (UJ), Finland; SINTEF Materials and Chemistry, Norway; Risø National Laboratory, Technical University of Denmark
    Funding: S-faculty, SLU; WoodWisdom-Net
    Period: 0901–
    Abstract: It is of great importance to evaluate the performance and stability of new methods. It is often hard to do so, when working with natural materials, since no true answer is available. With this project we aim to create highly realistic reference images that can be used to evaluate new and existing methods designed for µCT images of fibrous materials.

    So far, the project has resulted in a method to generate and pack synthetic wood fibres, and a software simulation of the µCT acquisition system that is capable of reproducing characteristic artifacts, see Fig, 6.



(a) (b)

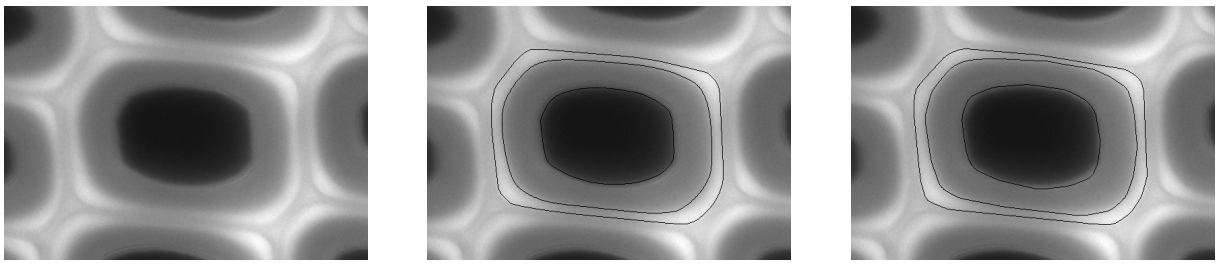
Figure 6: (a) A synthetic and automatically generated fibre. (b) Cross section of a synthetic model with noise.

11. **Direct Curvature Calculation of Surfaces in 3D Volumes**
    Erik Wernersson, Cris Luengo, Anders Brun, Gunilla Borgefors
    Funding: S-faculty, SLU
    Period: 1009 –
    Abstract: Curvature is known as a useful local descriptor of 2D surfaces, embedded in 3D space with applications ranging from visualisation to segmentation. With this project, we aim to find elegant ways to calculate curvature directly from volumetric data which might be flawed with artifacts and noise. No intermediate surface representations are used to ensure stability. The methods will be useful in the analysis of microCT images of composite materials where curvature can be used as a descriptor of several local properties of wood fibres.

12. **Segmentation and Measurement of Compression Wood Cross-Sections**
    Bettina Selig, Cris Luengo, Gunilla Borgefors
    Partner: Dept. of Forest Products, SLU
    Funding: S-faculty, SLU

Period: 0709–
Abstract: The properties of wood fibers are important for the performance of wood and fiber products. Compression wood is of limited value in the forest product industry, since its fibers are stiffer and more difficult to collapse compared to normal wood. But because it is difficult to completely avoid compression wood a better understanding of it is needed in order to develop mathematical prediction models of wood mechanics.

We have developed a method that automatically segments and measures different attributes of wood fibers from fluorescence microscope images of compression wood cross-sections. The results were compared to manual segmentations defined by experts. Fig. 7 shows an example for the automatic and manual delineation. The outer two segmentations lines (see Fig. 7(a) and (c)) agreed to a satisfying degree. For the inner segmentation line (separating lumen and cell wall) the automatic method set the boundary slightly further inward compared to the manual delineation. This caused an systematic error which can be corrected for. Descriptions of the algorithms and experiments were submitted for journal publication.



(a) (b) (c)

Figure 7: Segmentation of wood fibers from fluorescence microscope images of compression wood cross-sections. (a) Example cell. (b) Automatic segmentation. (c) Manual segmentation by expert.

13. **Image Analysis for Grain Quality Assessment**
Cris Luengo
Partners: Lantmännen Lantbruk (Lidköping & Uppsala), Maxx automation AB (Uppsala)
Funding: Lantmännen Lantbruk
Period: 1006–
Abstract: In this project we have developed novel algorithms to assess the quality of a batch of grain (oats, barley, wheat) as it is fed through the Seedscanner 2003 seed sorting robot. The algorithms estimate the proportion of grains that are discolored, burned, sprouted, molded, or damaged on other ways. Development of these and other algorithms continues, as well as hardware modifications to the robot to improve the imaging.

14. **Log end Feature Extraction of Untreated Wood Logs in Saw Mill Environment.**
Kristin Norell, Stina Svensson, Gunilla Borgefors
Partners: The Swedish Timber Measurement Council; Dept. of Forest Products and Markets, SLU
Funding: The Swedish Timber Measurement Council; S-faculty, SLU
Period: 0505 –
Abstract: The wood quality of a log can be determined to some extent by examining the log end. Such analysis is performed manually at sawmills, where a grader has a couple of seconds to determine features like the approximate annual ring density, presence of rot and presence of compression wood and at the same time take into account information about size and shape of the log as it passes on a conveyor. By using computerized image analysis, grading the number of annual rings

can be more robust and take some work load off the grader. In this project, methods to measure properties of logs in saw mill environment using computerized image analysis is developed.

The images used are log end images of Norway spruce (*Picea abies* (L.) H.Karst) and Scots pine (*Pinus sylvestris* L.) captured in a sawmill environment. Logs are sawn with a regular harvester or chainsaw and stored for various times before imaging. The end faces are depicted using either a system camera or an a camera more suitable for industrial applications mounted at the measurement station at Setra Group Nyby sawmill.

15. **Detection of Rot in End Faces of Wood Logs**
Kristin Norell, Stina Svensson, Gunilla Borgefors
Partners: Kim Dralle, Anders Björholm Dahl, Dralle A/S, Copenhagen, Denmark
Funding: S-faculty, SLU; Stiftelsen Mauritz Carlgrens fond
Period: 0612 – 1005
Abstract: The focus of this project is image analysis methods for identifying rot in log end faces. The purpose is to detect rot already while harvesting, or when the logs are in a stack waiting for transport. Logs are depicted using a standard color digital camera that can be mounted on a harvester or a vehicle. The goal is to find a robust method for detecting rot in timber suitable for practical use.

16. **Generating Synthetic Log end Face Images**
Kristin Norell, Gunilla Borgefors
Partners: The Swedish Timber Measurement Council; Dept. of Forest Products and Markets, SLU
Funding: The Swedish Timber Measurement Council; SLU S-faculty
Period: 0901–1012
Abstract: A small dataset or lack of ground truth can be a problem when developing and evaluating image analysis methods. In such cases synthetic images can be useful as a complement to real data. In this project a generator for synthetic end face images was developed.

End face features are generated according to the procedure of tree growth, including annual rings, knots, heartwood and bark. Also other features are simulated, such as unevenness and roughness from harvesting, camera setup, illumination, and imaging, including colour noise due to Bayer filtering.

5.3 Analysis of Microscopic Biomedical Images

17. **Analysis of Rat Embryo Heart Activity**
Khalid Niazi, Ewert Bengtsson
Partners: Mats Nilsson, Div. of Toxicology, Dept. of Pharmaceutical Biosciences, UU; Prof. Bill Webster, School of Medical Sciences, University of Sydney
Funding: COMSATS IIT, Islamabad
Period: 0711–
Abstract: Embryo cultures of rodents is an established technique for monitoring adverse effects of chemicals on embryonic development. The assessment involves determination of the heart rate of the embryo. We have modeled the movement of the heart as a sinusoid and developed a method to represent the heart motion as a function of time. Analysis of the heart beats were carried out using Emperical Mode Decomposition (EMD).

EMD is a powerful data analysis technique which decomposes complicated signal into intrinsic mode functions (IMF). EMD is usually combined with Hilbert transform to analyze the instantaneous frequency in non-stationary signals. This combination is commonly referred to as Hilbert-Huang Transform (HHT). In this project, we have used EMD with slight modification along with

Laplacian Eigenmaps to detect periodic activity in rat embryo's heart. The normal embryo's heart activity can easily be detected by local maxima detection but it becomes a challenging task once the heart activity becomes abnormal.

The motion of red blood cells in a vessel also indicates the effects of chemicals on the embryonic development. Currently, we are exploring different methods to analyse the motion of red blood cells.

18. **Scoring of Developmental Stages of Morphological Features of Rat Embryos**
Khalid Niazi, Ewert Bengtsson, Ingela Nyström
Partners: Mats Nilsson, Lennart Dencker, Div. of Toxicology, Dept. of Pharmaceutical Biosciences, UU
Funding: COMSATS IIT, Islamabad; Swedish Research Council
Period: 0909–
Abstract: The whole embryo culture assay is endorsed as one of few good in vitro embryotoxicity assays available. The goal of the project is to improve the objectivity and sensitivity in the measurements with the help of image and data analysis methods in the assay using three clinical relevant anti-epileptic drugs as model embryotoxicants.

The scoring methods used for morphology are generally semi-quantitative (categorical, score) and mainly associated with growth rate. Specific malformations are scored as either absent (=0) or present (=1). We propose to complement existing scoring systems that will improve embryotoxicity comparisons between labs and enable the creation of a database with cross-reference ability to molecular biology data and to automated image analysis system. Currently, we are focused on creating descriptors for the different organs. The ground truth data will be available from March 2011, which will allow us to test our descriptors.

19. **Parallax Error Correction in Retinal Image Registration**
Khalid Niazi, Bettina Selig, Ewert Bengtsson, Ingela Nyström
Partner: Albert Alm, Dept. of Neurosciences, UU
Funding: COMSATS IIT, Islamabad
Period: 0711–
Abstract: Retinal imaging is one of the main sources in ophthalmology to study the optical nerve head and the retina. Retinal images are often used for analyzing, diagnosing and treating a number of diseases of the human retina. Image registration plays an important role in determining the progression of retinal illness. In the current project, we are developing a method which will help in evaluation of glaucoma progression. We are especially concentrating on correction of parallax error, which is normally produced due to a change in the angular position of the camera.

Retinal image registration can be performed between either the full images or within sub-regions. The movement of vessels makes it illogical to perform registration between full images. Using a sub-region which is least effected by vessel movement will present a true picture of the vessel movement. The vessels inside the optic disc, which lie close to the origin, move with time and often get over-exposed during imaging. It has also been reported that the end of the vessel gets detached from the surface of the retina due to loss of the nerve fibers, which leaves us to use the area around the border of the optic disc. We have used the conventional particle swarm optimization (PSO) algorithm which uses uniform distribution to update the velocity equation. Subsequently, we have modified the PSO algorithm which utilizes benefits from the Gaussian and the uniform distribution, when updating the velocity equation. Which one of the distributions is selected depends on the direction o f the cognitive and social components in the velocity equation. This direction checking and selection of the appropriate distribution provide the particles with an ability to jump out of

local minima. The registration results achieved by this new version proves the robustness and its ability to find a global minimum.

Our algorithm and results were presented at the SSBA symposium held in Uppsala in March 2010.

20. **Automatic, Quantitative Malignancy Grading of Prostate Cancer using Image Analysis**
Ingrid Carlbom, Milan Gavrilovic, Ewert Bengtsson, Jimmy Azar
Partners: Christer Busch, Marene Landström, Dept. of Genetics and Pathology, UU Hospital
Funding: Swedish Research Council
Period: 1001–
Abstract: Prostate cancer diagnosis is based on Gleason grading, which is the most widely used system for determining the severity of prostate cancer from tissue samples. However, Gleason grading is highly subjective with significant variation between experienced pathologists, which studies show may be as high as 30-40%. We propose to replace subjective diagnosis of prostate cancer with automatic severity grading using a combination of tissue staining and image analysis. New stain combinations enhance color contrast, allowing automatic measurements of morphological features of glands and cells, and thus allowing us to take advantage of computer vision and quantitative image analysis rather than relying on human vision. We intend to demonstrate the accuracy of our severity grading by using the consensus Gleason-graded cohorts from several existing collections of prostate biopsy and prostatectomy material. During 2010, we developed a new staining method particularly suited for image analysis of prostate histopathological data and a technique for color decomposition of these images. By using a combination of histochemical and immunohistochemical staining procedures, we have made it possible to discriminate between normal glandular structures and infiltrating cancer. Thereby we can exclude normal glands from cancer and derive the morphological patterns that characterize malignancy grade progression in these patterns. By using a color model that extracts spectral components of the tissue, we remove the intensity variations that are artifacts from the sectioning and staining procedures. Furthermore, statistical techniques for noise modeling and clustering use soft classification rules allowing linear color decomposition. The purpose is to label each region of the histopathological sections according to its severity grade by employing quantitative image analysis.

21. **Spectral Image Analysis in Biomedical Applications**
Milan Gavrilovic, Carolina Wählby
Partners: Irene Weibrecht, Tim Conze, Ola Söderberg, Ulf Landegren, Dept. of Genetics and Pathology, UU
Funding: TN-faculty, UU
Period: 0807–
Abstract: Our previously published novel methods for quantification of colocalization are applied to a number of projects in collaboration with the Molecular Tools group at the Dept. of Genetics and Pathology. The aim is detection of multicolour rolling circle products representing DNA-protein interactions in wide-field fluorescence microscopy images. In addition, we use the methods for evaluation of biochemical methods relevant in early stages of specimen preparation, e.g., estimating the quality of oligonucleotides.

22. **Automation of Animal Positioning and Brain Cell Counting in Zebrafish**
Amin Allalou, Carolina Wählby
Partners: Carlos Pardo and Mehmet F. Yanik, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, USA
Funding: TN-faculty, UU
Period: 1009–
Abstract: During 2010 a research visit was conducted to MIT, Cambridge, USA, and a collabora-

tion was initiated.
A high-throughput platform for cellular resolution *in vivo* chemical and genetic screens on zebrafish has been developed at MIT, Cambridge, USA. The system automatically loads zebrafish larvae and positions and rotates them for high-speed confocal imaging. The number of neurons in the fish is of importance to different screens and therefore a method has been tested to count the number of neurons in certain regions of the zebrafish brain. In addition, some methods have been developed to rotate and align the fish correctly before imaging.

23. **A Multidisciplinary Approach to Establish Mechanisms for Mitochondrial DNA Segregation in Human Disease**
Amin Allalou, Carolina Wählby
Partners: Nils-Göran Larsson, Karolinska Institute; Mats Nilsson, Chatarina Larsson, Dept. of Genetics and Pathology, UU
Funding: The Swedish Research Council, Collaboration Grant, Medicine
Period: 0801–
Abstract: Mutations of mitochondrial DNA (mtDNA) cause genetic syndromes with widely varying phenotypes and are also implicated in many age-associated diseases and the ageing process itself. Our knowledge of the principles governing segregation of mtDNA mutations in somatic tissues and in the germ line is very limited. In this collaborative project we combine a powerful technique for detection of individual mtDNA molecules with image analysis. We work with a variety of mouse models and the goal is to develop image analysis software to do three-dimensional (3D) reconstruction of the distribution of mutated mtDNA molecules in mammalian tissues. We want to use this technology to study segregation of mtDNA mutations in mouse tissues and to study the mtDNA bottleneck by visualizing the distribution of mutated mtDNA during oogenesis. The ultimate goal is to study the distribution of mtDNA mutations in embryos and placenta to establish principles for prenatal diagnosis.

24. **Multicolor Read-Out Increases the Dynamic Range of in situ PLA**
Amin Allalou, Ida-Maria Sintorn, Carolina Wählby
Partners: Carl-Magnus Clausson, Ola Söderberg, Dept. of Genetics and Pathology, UU
Funding: TN-faculty, UU; VINNMER programme, Swedish Governmental Agency for Innovation Systems
Period: 1002–
Abstract: A novel approach to increase the dynamic range of *in situ* PLA has been developed at Dept. of Genetics and Pathology, UU. Using several probes with different concentrations the dynamic range can be extended significantly. Signal detection previously developed at CBA, UU, (3DSWD) is used to quantify the number of signals in the different concentrations. See Fig. 8

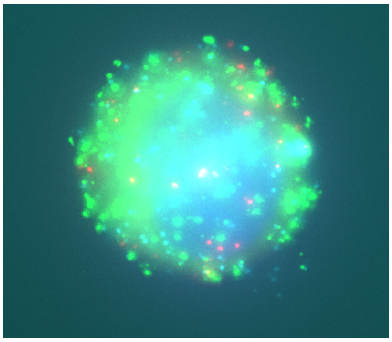


Figure 8: Image of three different fluorescent probes with different concentrations.

25. **High Content Analysis (HCA) Method Development for Cellular Screening**
Ida-Maria Sintorn
Partners: Adrian Baddeley, Michael Buckley, Leanne Bischof, CSIRO Mathematical and Information Sciences, Australia; Stephen Haggarty, Broad Institute of Harvard and MIT, USA
Funding: S-faculty, SLU; VINNMER programme, Swedish Governmental Agency for Innovation Systems
Period: 0901–
Abstract: In biological research and in the drug development process when screening for new drugs, HCA systems are often used. Such a system is a fully automatized microscopy system that acquires hundreds or thousands of images in an experiment and automatically extracts information from the image data. In this project we develop pre-processing tools to allow for improved comparison of image content within and across cellular screening experiments. During 2010 a method utilizing gradient information for intensity normalization between images was published (Sintorn et al. J. Microscopy). We also develop methods and new statistical analysis tools for so called co-culture HCA experiments i.e., when more than one celltype are cultured together to allow for investigating their interaction in response to added substrates.

26. **Analysis of Virus Morphology in Electron Microscopy Images**
Ida-Maria Sintorn
Partner: Vironova AB
Funding: VINNMER programme, Swedish Governmental Agency for Innovation Systems
Period: 0801–
Abstract: Electron Microscopy allows for studying the shape and morphology of biological particles such as viruses at the nm level. This means for example that structural differences between virus maturation stages, related virus species, wild type virus and virus treated with a potential drug or a small molecule can be analyzed. Both external (shape and protein patterns on the virus surface) and internal structural differences can be analyzed. In this project methods for efficiently identifying and quantifying such structural differences are developed.

27. **Identification of Highly Pathogenic Viruses in Transmission Electron Microscopy Images**
Gustaf Kylberg, Ida-Maria Sintorn, Ewert Bengtsson, Gunilla Borgefors
Partners: Vironova AB; Ali Mirazimi, Kjell-Olof Höglund, Centre for Microbiological Preparedness, Swedish Institute for Infectious Disease Control (SMI); Jan-Olof Strömberg and Joel Andersson, Dept. of Mathematics, Royal Institute of Technology.
Funding: S-faculty, SLU; Swedish Civil Contingencies Agency; Swedish Defense Materiel Administration; Swedish Governmental Agency for Innovation Systems
Period: 0801–
Abstract: This project is closely linked to Project 28. It aims at automating the virus identification process in high resolution TEM images and thereby creating a rapid, objective, and user independent virus diagnostic system. The task consists of method development for segmenting virus particles with different shapes and sizes in high magnification images and extracting descriptive features to enable classifying the virus species. So far the main focus has been segmenting and correctly delineating possible virus particles. Fig. 9 shows an example of a result of a method developed to refine the borders after a first preliminary segmentation. The watershed methods with seeds is applied to the a gradient magnitude image to refine the position of the object border. A totally different approach, using diffusion geometry to segment and identifying virus particles is investigated jointly with our collaborators at KTH.

In 2010 the project was presented together with Project 28 at the Swedish National Symposium on Technology and Methodology for Security and Crisis Management (TAMSEC) in Linköping, Sweden.

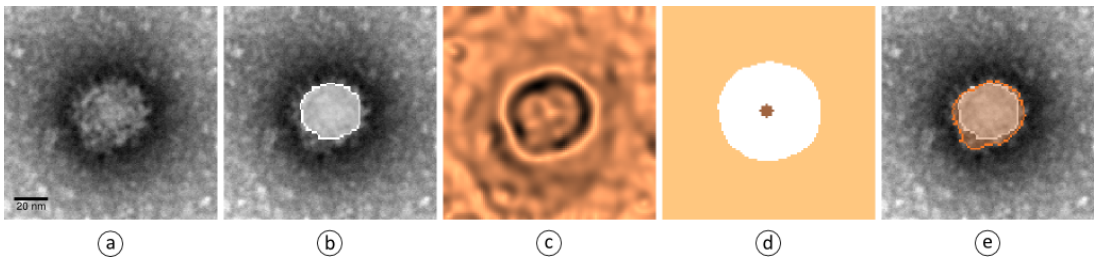


Figure 9: Refining object border after preliminary segmentation of a Dengue fever virus particle. a) original TEM image, b) preliminary segmentation c) Gaussian gradient magnitude d) Seeds for seeded watersheds e) refined object border.

28. **Detection of Regions of Interest for Automated Image Acquisition in Virus Diagnostics**
Gustaf Kylberg, Ida-Maria Sintorn, Ewert Bengtsson, Gunilla Borgefors
Partners: Vironova AB; Ali Mirazimi, Kjell-Olof Höglund, Centre for Microbiological Preparedness, Swedish Institute for Infectious Disease Control; Gun Frisk and Monika Hodik, Dept. of Immunology, Genetics and Pathology, UU
Funding: S-faculty, SLU; Swedish Civil Contingencies Agency; Swedish Defense Materiel Administration; Swedish Governmental Agency for Innovation Systems
Period: 0801–
Abstract: Transmission electron microscopy (TEM) is an important virus diagnostic tool. The main drawback is that an expert in virus appearance in electron microscopy is needed to perform the analysis at the microscope, an often very time consuming task.

    The project aim is to develop methods for a multi-scale analysis at the microscope to automatically acquire highly magnified images of possible virus particles. This is an important step towards automating the virus identification process and thereby creating a rapid, objective, and user independent virus diagnostic system. By introducing the multi-scale approach the search area where highly magnified images are acquired could be decreased by 99.99%. The subsequent segmentation and classification process is developed in Project 27. A collaboration has recently been initiated with Dept. of Immunology, Genetics and Pathology, Uppsala University, based on the common interest of automated virus detection using TEM. The project was presented together with Project 27 at the Swedish National Symposium on Technology and Methodology for Security and Crisis Management (TAMSEC) in Linköping, Sweden.

29. **Analysis of Male Reproductive Tract Morphology in Reproductive Toxicology**
Azadeh Fakhrzadeh, Cris Luengo, Gunilla Borgefors
Partners: Ellinor Spörndly-Nees, Lena Holm, Dept. of Anatomy, Physiology and Biochemistry, SLU
Funding: SLU (KoN)
Period: : 1009–
Abstract: Reproductive toxicology is the study of chemicals and their effects on the reproductive system of human and animal. In reproductive toxicology, there is a strong need to detect structural differences in organs that often have both a complex microscopic structure and function. This problem is further complicated because standard techniques are based on the examination of two-dimensional sections of a three-dimensional structure. The aim of this project is to develop methods to objectively describe microscopic structures of male reproductive organs and to test these in reproductive toxicology research. The project is comparative and may include studies of organs from fish, frog and birds as well as wild and domesticated mammals. We will develop automatic and interactive methods to analyze the relevant structures in the histology images of testis,

see Fig. 10. There will probably be need for both adaptation of known methods and development of completely new ones. The work will therefore be both applied and theoretic.

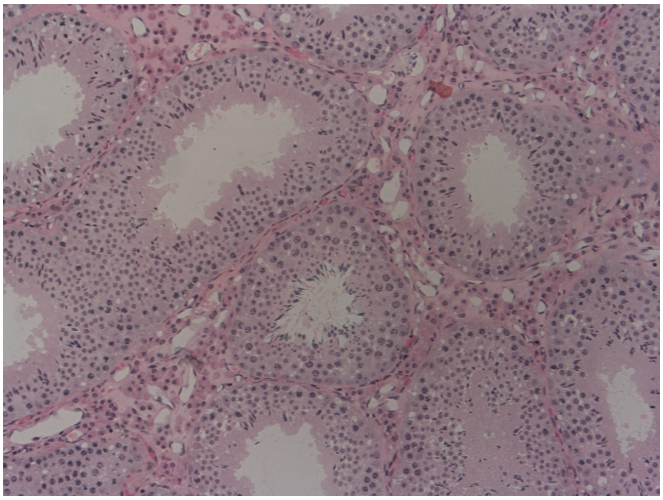


Figure 10: Histology image of the testis.

30. **New Objective Quantitative Analysis Techniques for Quantification of Tissue Regeneration Around Medical Devices**
Hamid Sarve, Joakim Lindblad, Vladimir Curic, Gunilla Borgefors
Partners: Carina Johansson, Dept. of Clinical Medicine, Örebro University; Nataša Sladoje, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: Swedish Research Council; S-faculty, SLU
Period: 0503–
Abstract: With an aging and increasingly osteoporotic population, bone implants are becoming more important to ensure the quality of life. In order to evaluate how tissue reacts on implants, the interface at the implant and tissue must be studied. Today, this is done manually in a microscope which is a costly and time-consuming procedure.

The aim of this project is to develop automatic image analysis methods for evaluating images of the interface region of tissue and implant. These methods would provide faster and more objective measurements on how well the implant is integrated in the bone compared to today's manual methods. The analysis involves segmentation of the images into different tissue-types and quantifying bone contact length, area and volume.

The project encompasses parallel development and comparison of methods for 2D analysis of histological sections as well as 3D analysis of SRμCT volumes. Within the project, methods for segmentation and feature extraction have been developed for both 2D histological sections, and 3D SRμCT volumes. To facilitate comparison of results from the two imaging modalities, a 2D-3D image registration method has also been developed. During 2010, by extending the features traditionally used for 2D analysis, methods for extraction of the 3D features from the 3D volume data were developed. This work was accepted for publication in the Journal of Computer Methods and Programs in Biomedicine.

31. **Assessing Bone Implant Integration From Synchrotron micro-CT Data**
Hamid Sarve, Joakim Lindblad, Gunilla Borgefors
Partners: Carina Johansson, Dept. of Clinical Medicine, Örebro University; AstraTech, Mölndal
Funding: The Knowledge Foundation

Period: 0906–

Abstract: This project aims to develop new techniques for interactive 3D visualization of bone anchored implants in order to facilitate the understanding of the mechanisms of implant integration. To enable good communication between the people involved in development, production and use of medical devices – computer scientists, material scientists, and medical doctors – each with their own special knowledge, it is of highest importance to provide a common visual platform for a mutual understanding of the problems of implant integration. Being able to actually see the 3D structure around the implant for the first time will inspire new measures of the implant integration quality.

We base the visualization on data from non-destructive 3D SRμCT imaging; this technique yields more accurate tomographic reconstruction at higher resolution compared to standard CT. Furthermore, SRμCT-imaging is more suitable for samples containing metal, as the artefacts caused by the metal is significantly lower compared to traditional CT. Existing visualization software are not really useful for this type of complex and highly detailed data, requiring the development of special purpose methods and software.

The combination of this project and Project 30 will improve both quantitative and qualitative analysis of bone implant integration and thereby support the development of more effective implants and diminish the number of malfunctioning devices. During 2010, two new methods for visualizing SRμCT-scanned volume samples were presented at the International Conference on Computer Vision and Graphics (ICCVG'10); one being an animation that follows the implant thread and extracts information about the bone-implant integration over the whole sample and the other a 2D unfolding that displays a flattened version of the implant surface, with feature information projected onto it, providing a direct overview of the implant integration (see Fig. 11).

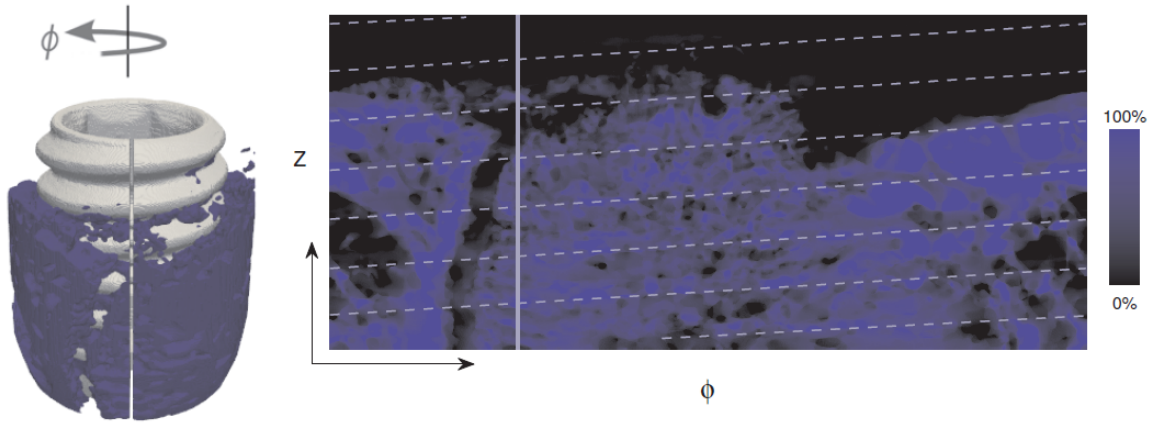


Figure 11: (Left) Rendered surface of the implant with bone tissue volume in the region of interest superimposed. (Right) The unfolded surface, where the blue regions indicate high concentration of bone tissue (see the bar to the right). White dashed lines show the peaks of the threads. The vertical line indicates the corresponding angles in the two images.

32. **Automated Localisation of Macromolecules in Cryo Electron Tomographic Data**
Stina Svensson, Magnus Gedda
Partner: Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm
Funding: Swedish Research Council (Project 621-2005-5540); SLU S-faculty; UU TN-faculty
Period: 0401-1005
Abstract: State of the art imaging techniques makes it possible to study individual proteins and other macromolecules from a structural point of view. Descriptions with respect to geometry and shape facilitates studying protein dynamics. This type of study is essential to increase the understanding of their biological role. CMB has developed methods, using cryo electron tomography (Cryo-ET), for 3D imaging of individual proteins at a resolution of a few nm. Localisation of the protein in the image has so far been done manually. For large-scale studies, computerized image analysis serves as an essential tool to automatically and objectively analyse image content. In this project, we develop methods to automatically localise macromolecules from in vitro Cryo-ET images and thereby make large-scale studies of proteins possible. This is done by taking into account both grey-level information (which reflects the internal structure of the protein) and 3D shape information.

33. **Combating Breast Cancer by Digital Pathology**
Andreas Kårsnäs, Robin Strand, Ewert Bengtsson, Stefan Seipel
Partners: Visiopharm, Hörsholm, Denmark; Clinical Pathology Division, Vejle hospital, Vejle, Denmark
Funding: NordForsk Private Public Partnership PhD Programme and Visiopharm
Period: 0909–
Abstract: The results of analyses of tissue biopsies by pathologists are crucial for breast cancer patients. In particular, the precision of a patient's prognosis, and the ability to predict the consequences of various treatment opportunities before actually exposing the cancer patient, depend on the detection and quantification of biomarkers in tissue sections by microscopy. Experience from the last decade has revealed that manual detection and quantification of biomarkers by microscopy of tissue biopsies is highly dependent on the competencies and stamina of the individual pathologist. The aim of the present PhD project is to develop software-based algorithms, which can facilitate the workflow and ensure objective and more precise results of the quantitative microscopy procedures in breast cancer. During spring 2010, we finished the first part of the development of the Pathology Module, a user interface supporting pathologists while ensuring objective and more precise results of the quantitative microscopy procedures in breast cancer. During the fall 2010, we have started a project for automatic detection of cancer cells. The main focus has been on detecting cell nuclei, and we have, in collaboration with DTU in Denmark, developed an algorithm for nuclei-detection and separation of co-localized nuclei.

5.4 3D Analysis and Visualization

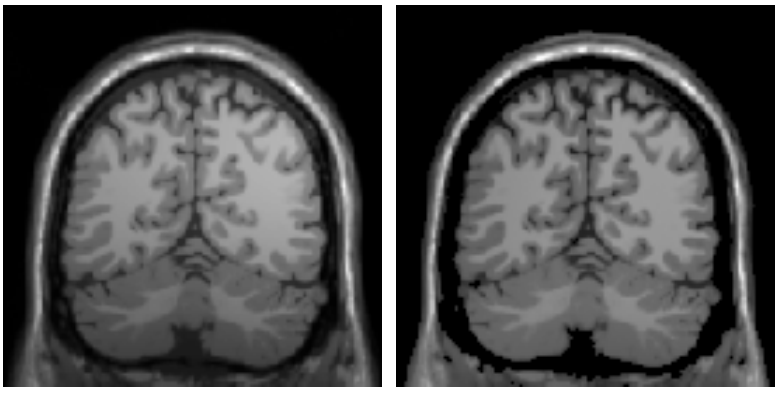
34. **Analysis and Processing of Three-Dimensional Magnetic Resonance Images on Optimal Lattices**
Elisabeth Linnér, Robin Strand
Partner: Joel Kullberg, Dept. of Radiology, Oncology and Radiation Science, UU
Funding: TN-faculty, UU
Period: 1005–
Abstract: Most three-dimensional image acquisition methods are based on tomography, i.e., the three-dimensional image is constructed by a stack of two-dimensional images, each acquired separately. To take full advantage of the high sampling efficiency of the optimal lattices, the image should be acquired as a full three-dimensional image. This is possible in magnetic resonance imag-

ing. In this project, methods for image acquisition, analysis, and visualization will be developed for magnetic resonance images represented on non-standard lattices.

With the methods developed in this project, it will be possible to process three dimensional images with 30% less data without affecting the image quality. Our intention is that this project will lead to faster processing of images with less demands on the data storage capacity.

35. **Statistical Classification of Voxels in Micro-CT Images**
Robiël Naziroglu, Catherine Östlund, Cris Luengo
Partner: Innventia AB, Stockholm
Funding: VINNMER programme, Swedish Governmental Agency for Innovation Systems
Period: 1008–1012
Abstract: A new table-top micro-CT device was installed at Innventia in 2010. We studied the device's noise characteristics, the relationship between the noise in the raw data and that in the reconstructed volumetric data, the effect on the image of different exposure times, and the use of filters during acquisition. We developed a method to accurately estimate the local volume fraction of fibre in images of paper and cardboard. We also investigated the correlation between noise in neighbouring voxels in these images, and developed a method to more accurately classify voxels as fibre or air using these statistics.

36. **Illumination Correction in Medial Images**
Khalid Niazi, Ingela Nyström
Partners: M. Talal Ibrahim, Ling Guan, Ryerson Multimedia Lab, Ryerson University, Canada
Funding: COMSATS IIT, Islamabad
Period: 1003–
Abstract: Non-uniform illumination is considered as one of the major challenges in the field of medical imaging. It is often caused by the imperfections of the data acquisition device and the properties of the object under study. We have developed an iterative method which suppresses the magnitude of the frequencies that are responsible for non-uniformity in an image using the gray-weighted distance transform (GWDT). Moreover, the proposed method is not user dependent as all the parameters are automatically generated on the basis of the GWDT. It is tested on images acquired from several imaging modalities which makes it different and unique from most of the existing methods. Fig. 12(a) shows a slice from an MRI suffering from the non-uniform illumination, while Fig. 12(b) shows the result of the proposed method.



(a) (b)

Figure 12: a) A slice from an MRI suffering from non-uniform illumination. b) Result of the proposed method.

37. **Analysis of Dynamic Breast MRI**
Ewert Bengtsson, Ingela Nyström
Partners: Stuart Crozier, Andrew Mehnert, School of Information Technology and Electrical Engineering, University of Queensland, Brisbane, Australia, MedTech West
Funding: TN-faculty, UU; The Australian Research Council
Period: 0503–
Abstract: The pattern of change of signal intensity over time in dynamic contrast enhanced magnetic resonance images (DCE-MRI) of the breast is an important criterion for the differentiation of malignant from benign lesions. Malignant lesions release angiogenic factors which induce the growth and sprouting of existing blood vessels and the formation of new leaky vessels. This gives rise to increased inflow and an accelerated extra-vascularisation of contrast agent at the tumour site which is reflected as T1-weighted signal increase. However strong enhancement is not specific to malignant lesions. Contrariwise shallow or no enhancement is a feature of some malignant lesions. As a result the specificity of the technique is poor to moderate.

This project is seeking to improve the specificity of breast MRI, and therefore its clinical utility, in two ways. The first is by combining features describing enhancement with those describing lesion morphology and micro-structure. This involves integrating intrinsic contrast MRI with DCE-MRI and diffusion-weighted (DW) MRI. The second is by reducing subjectivity in routine clinical interpretation of breast MRI data by means of computer visualisation, image analysis, and statistical pattern recognition.

This collaborative project has evolved from one which Bengtsson joined during his sabbatical at the University of Queensland in 2004-2005. Significant outcomes to date include novel software and algorithms for motion correction and registration, registration evaluation, denoising, parametric modelling of contrast enhancement, 3D colour-coding of 4D DCE-MRI data, hardware-accelerated volume visualisation using a colour-preserving maximum intensity projection in the HSV colour space, haptic interaction/interrogation of the volumetric data, breast and lesion segmentation, feature (morphology, enhancement, and diffusion) extraction, and lesion classification. The project has also developed several plug-ins for the open source OsiriX platform specifically for visualisation, reporting/annotation, and image analysis/processing of breast MRI data. This software is currently being evaluated under license by a private radiology practice in Queensland.

Collaboration is continuing on the evaluation of the developed parametric models of enhancement as well as the development of DW-MRI features to characterise micro-structural changes in malignant tissue.

38. **ProViz – Interactive Visualization of 3D Protein Images**
Lennart Svensson, Ida-Maria Sintorn, Stina Svensson, Ingela Nyström, Anders Brun, Ewert Bengtsson
Partners: Dept. of Cell and Molecular Biology, Karolinska Institute; SenseGraphics AB
Funding: The Visualization Program by Knowledge Foundation; Vaardal Foundation; Foundation for Strategic Research; Swedish Governmental Agency for Innovation Systems; Invest in Sweden Agency
Period: 0807–
Abstract: The traditional methods for solving the structure of proteins are X-ray crystallography and NMR spectroscopy. An alternative approach, Molecular Electron Tomography (MET), has more recently gained interest within the field of structural biology as it enables studies of individual structures in tissue at nanometer scale, whereas the old methods only allowed studies in solution. Additionally, MET enables studies of the dynamics of proteins. MET results in images of low resolution, as compared with e.g., X-ray crystallography, and low signal-to-noise ratio. A new kind of software for postprocessing is hence required, which allows for proper visualization

and analysis, as well as data fusion with measurements from X-ray crystallography and NMR. The target of the ProViz project is to create these software tools. Our approach is to use stereo visualization and haptic rendering of the images in order to facilitate a good understanding of the data as well as interactivity in semi-automatic methods.

During 2010, we have focused on developing methods for automatic transfer function generation for volume rendering of MET data-sets. A paper investigating different image properties for automatically generating a suitable transfer function will be presented at the International conference on Computer Graphics, Visualization and Computer vision early 2011. We have also investigated methods for visualizing the goodness of fit when matching or docking other types of data (e.g. X-ray crystallography data) in the MET volumes. See example in Fig. 13.

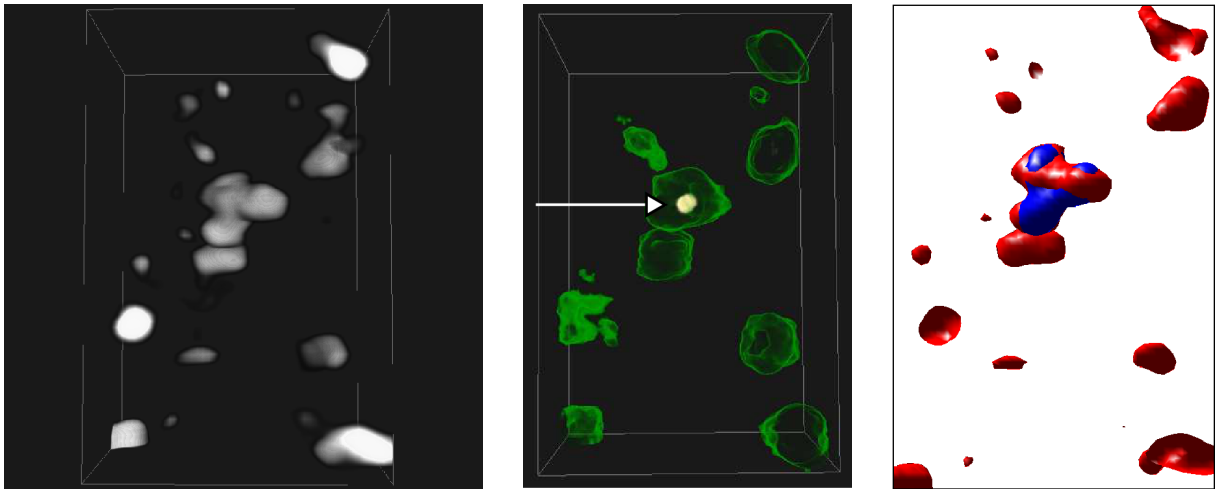


Figure 13: Registration with a protein template in a MET volume. The original volume to be searched is shown to the left, in the middle is a volume depicting the value of a fitting function for different positions of the template molecule (the best and correct position is marked with an arrow), and on the right is the corresponding registration, with the template molecule in blue.

39. **Improved Interactive Medical Image Analysis through Haptic Display Methods**
Filip Malmberg, Ingela Nyström, Ewert Bengtsson, Stefan Seipel
Partners: Gunnar Jansson, Dept. of Psychology, UU;
Funding: Swedish Research Council; TN-faculty, UU
Period: 0301–
Abstract: Modern medical imaging techniques provide 3D images of increasing complexity. Better ways of exploring these images for diagnostic and treatment planning purposes are needed. Combined stereoscopic and haptic display of the images form a powerful platform for such image analysis. In order to work with specific patient cases, it is necessary to be able to work directly with the medical image volume and to generate the relevant 3D structures as they are needed for the visualization. Most work so far on haptic display use predefined object surface models. In this project, we are creating the tools necessary for effective interactive exploration of complex medical image volumes for diagnostic or treatment planning purposes through combined use of haptic and 3D stereoscopic display techniques. The developed methods are tested on real medical application data. Our current applications are described further in Projects 44, 37, 40, and 42.

A software package for interactive visualization and segmentation developed within this project has been released under an open-source license. The package, called WISH, is available for download at `http://www.cb.uu.se/research/haptics`.

40. **Interactive Segmentation of Back Muscles in MR Images**
Filip Malmberg, Ewert Bengtsson, Ingela Nyström
Partners: Andrew Mehnert and Craig Engstrom, ITEE Dept., University of Queensland, Brisbane, Australia
Funding: TN-faculty, UU; The Australian Research Council
Period: 0803–
Abstract: In cricket fast bowlers, substantial volume asymmetries of the quadratus lumborum (QL) muscle have been associated with a significantly increased risk of developing lumbar spine stress fractures. In this project, we aim to measure such asymmetries by segmenting the QL muscle in MR images. At the University of Queensland, an automatic segmentation method has been developed for this purpose. The method uses a shape atlas, built from a large number of reference segmentations, to segment a specific muscle. Currently, we are investigating if interactive segmentation methods can be used to accelerate the creation of reference segmentations. By accelerating this process, we make it easier to adapt the atlas-based automatic segmentation method to other interesting muscles. A 3D visualization of a segmented QL muscle is shown in Fig. 14. In 2010, this project was presented at the SPIE Medical Imaging conference in San Diego.

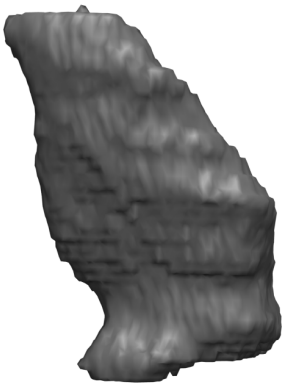


Figure 14: Surface rendering of a segmented Quadratus Lumborum muscle.

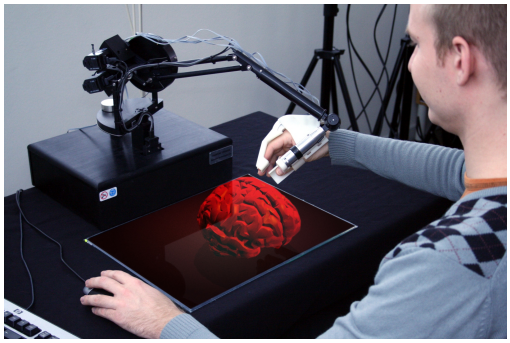
41. **Whole Hand Haptics with True 3D Displays**
Ingrid Carlbom, Ewert Bengtsson, Filip Malmberg, Ingela Nyström, Stefan Seipel, Pontus Olsson, Robin Strand, Martin Ericsson, Fredrik Nysjö
Partners: Stefan Johansson (Teknovest AB); Jonny Gustafsson and Lars Mattson, Industrial Metrology and Optics Group, Royal Institute of Technology; Jan-Michaél Hirsch, Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU, Consultant at Dept. of Plastic- and Maxillofacial Surgery, UU Hospital; Roland Johansson, Dept. of Neurophysiology, Umeå University; Håkan Lanshammar, Kjartan Halvorsen, Dept. of Information Technology, UU; PiezoMotors AB, SenseGraphics AB
Funding: Knowledge Foundation
Period: 0908–
Abstract: We are building an augmented reality system that will allow users to touch and manipulate high contrast, high resolution, three-dimensional virtual objects suspended in space using a glove that gives realistic whole hand haptic feedback both in terms of force feedback to the wrist and finger joints and tactile feedback to the fingertips. The driving application is craniomaxillofacial surgery, giving a surgeon the ability to plan complex procedures, moving bone and implants into their desired positions and then stretching the soft tissue to accommodate the struc-

tural changes. However, the system may also significantly enhance other applications in, for example, computer-aided design, training simulators for object assembly, and 3D games.

During 2010 we assembled the first generation display system with a Holographic Optical Element and evaluated its rendering fidelity, latency, and perceived 3D-accuracy, resulting in several new design criteria for the next generation display, including a more optimal separation of the adjacent views. Perspective correction (keystone correction) warps the images from the projectors so that they coincide, and a commercial head tracker enables removal of the discontinuities between adjacent views. We also designed a series of interaction experiments to evaluate the feasibility of co-located haptic interaction with the Holographic Optical Element.

The first generation haptic glove acts as an external skeleton with the hand and finger joints controlled by actuators that are integrated into the glove (Fig. 15). This first prototype has six degrees of freedom (DOF) movement of the hand and one DOF gripping with the thumb and index finger. The six DOF movements are accomplished with a commercial haptic arm, the SensAble Phantom Premium, while the gripping haptic glove is developed within this project. The gripping force is controlled by the most compact, high-precision piezoelectric motor that is commercially available today, a piezoelectric motor from Piezomotor AB, using a separate force sensor in a feed-back loop. The high stiffness of the motor in combination with a very high dynamic speed range allows for delicate grip force control. This first single joint glove has identified the most important issues for subsequent generations: the actuators have to be further miniaturized with the speed increased, the audible sound eliminated, and the weight reduced.

We built a first tactile array prototype comprising a single array 1.4 x 1.4 mm element, intended for an array with 2 mm pitch. Tests show that this type of solution can be used in array formats and that each element can generate lateral forces. The lateral speed is about 5 mm/sec that is close to the final requirement. It is also possible to move objects with very small mass that is required for skin stimuli. The design is based on piezoelectric bimorphs that can be surface mounted on flexible printed circuit boards, i.e., the design is already prepared for industrial production. The ultimate solution will require further development to fulfill all requirements.



(a)

Figure 15: The first generation of a haptic glove with seven degrees of freedom. It consists of plastic parts and one modified LEGS®-motor for force feed-back. The glove is suspended from a commercial robot arm (black and blank metal), which is shown in combination with the holographic display.

42. **Orbit Segmentation for Craniomaxillofacial Surgery Planning**
Filip Malmberg, Ewert Bengtsson, Ingela Nyström
Partners: Jan Michael Hirsch, Elias Messo, Dept. of Surgical Sciences, UU Hospital
Funding: TN-faculty, UU; NovaMedTech
Period: 0912–

Abstract: A central problem in cranio-maxillofacial (CMF) surgery is to restore the normal anatomy of the skeleton after defects, i.e., malformations, tumors and trauma to the face. This is particularly difficult when a fracture causes vital anatomical structures such as the bone segments to be displaced significantly from their proper position, when bone segments are missing, or when a bone segment is located in such a position that any attempt to restore it into its original position poses considerable risk for causing further damage to vital anatomical structures such as the eye or the central nervous system. There is ample evidence that careful pre-operative planning can significantly improve the precision and predictability and reduce morbidity of the craniofacial reconstruction. In addition, time in the operating room can be reduced. An important component in surgery planning is to be able to accurately measure the extent of certain anatomical structures. Of particular interest in CMF surgery are the shape and volume of the orbits (eye sockets) comparing the left side with the right side. These properties can be measured in CT images of the skull, but this requires accurate segmentation of the orbits. Today, segmentation is usually performed by manual tracing of the orbit in a large number of slices of the CT image. This task is very time-consuming, and sensitive to operator errors. Semi-automatic segmentation methods could reduce the required operator time significantly. In this project, we are developing a prototype of a semi-automatic system for segmenting the orbit in CT images. Segmentations obtained with this system are shown in Fig. 16.

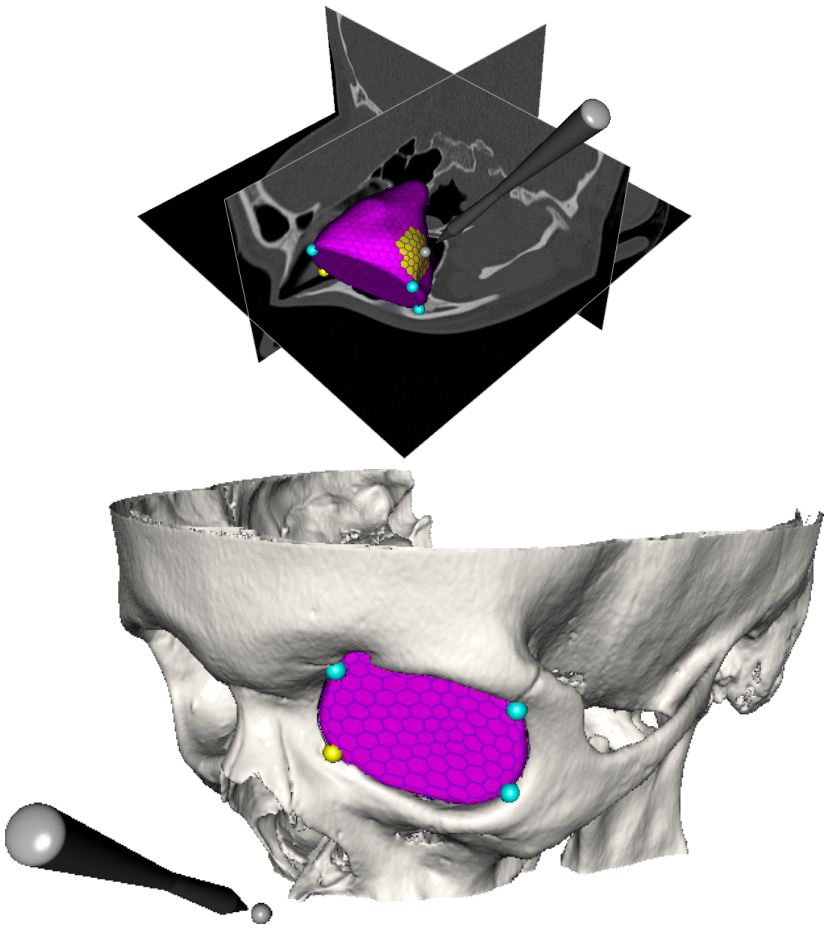


Figure 16: (Top) Segmentation of the orbit in a CT image using a deformable model. (Bottom) Final segmentation of the orbit, visualized with the skull surface.

43. **Improved Methods for Interactive Graph-Based Segmentation**
Filip Malmberg, Ingela Nyström, Ewert Bengtsson
Funding: TN-faculty, UU
Period: 0901–
Abstract: Image segmentation, the process of identifying and separating relevant objects and structures in an image, is a fundamental problem in image analysis. Accurate segmentation of objects of interest is often required before further processing and analysis can be performed. Despite years of active research, fully automatic segmentation of arbitrary images remains an unsolved problem.

Seeded segmentation methods attempt to solve the segmentation problem in the presence of prior knowledge in the form of a partial segmentation. Given an image where a small subset of the image elements (called *seed-points*) have been assigned correct segmentation labels (e.g., object or background), an automatic algorithm completes the labeling for all image elements. The seed-points may be provided either by some automatic pre-processing algorithm, or by a human user in an interactive setting.

This project concerns the development of general tools for interactive seeded segmentation. In particular, we are studying methods based on the Image Foresting Transform (IFT). A method for incorporating smoothness into the IFT framework was presented at the SPIE Medical Imaging 2010 conference. An illustration of a segmentation obtained with this method is shown in Fig. 17. A theoretical framework for performing graph-based segmentation with sub-pixel precision has also been developed, in close collaboration with Project 6.

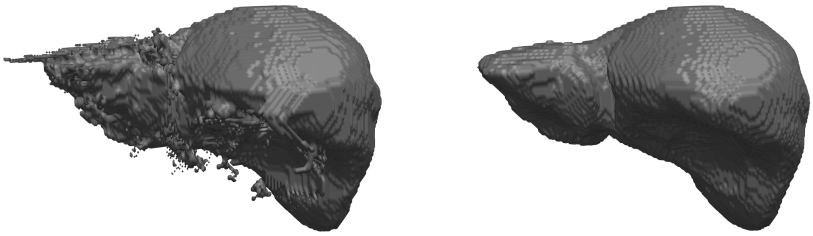


Figure 17: Segmentation of the liver in a MR volume image, using the relaxed IFT. Seed-points representing liver and background are placed interactively by a human operator. (Left) Due to noise and low contrast between the liver and adjacent organs, e.g., the heart, the IFT produces a highly irregular segmentation. (Right) A smoother segmentation, obtained using a relaxation procedure developed within Project 43.

44. **Interactive Organ Segmentation from Abdominal CT Images**
Filip Malmberg, Ingela Nyström, Ewert Bengtsson
Partners: Sven Nilsson, Milan Golubovic, Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
Funding: Swedish Research Council; TN-faculty, UU
Period: 0501–
Abstract: The manual step in semi-automatic segmentation of medical volume images typically involves initialization procedures, such as placement of seed-points or positioning of surface models inside the object to be segmented. The initialization is then used as input to an automatic segmentation algorithm. We investigate how such initialization tasks can be facilitated by using haptic feedback. In this project, we develop interactive methods for segmenting the organs from abdominal CT scans. For example, liver segmentation is of importance in hepatic surgery planning, where it is a first step in the process of finding vessels and tumours, and the classification of liver segments. Liver segmentation may also be useful for monitoring patients with liver metastases, where disease progress is correlated to enlargement of the liver. We have developed a fully

3D liver segmentation method where high accuracy and precision is efficiently obtained via haptic interaction in a 3D user interface. Our method makes it possible to avoid time-consuming manual delineation, which otherwise is a common option prior to, e.g., hepatic surgery planning. Currently, we are incorporating and adapting region-based segmentation methods, such as the image foresting transform (IFT), into our software. Fig. 18 illustrates interactive organ segmentation with IFT.

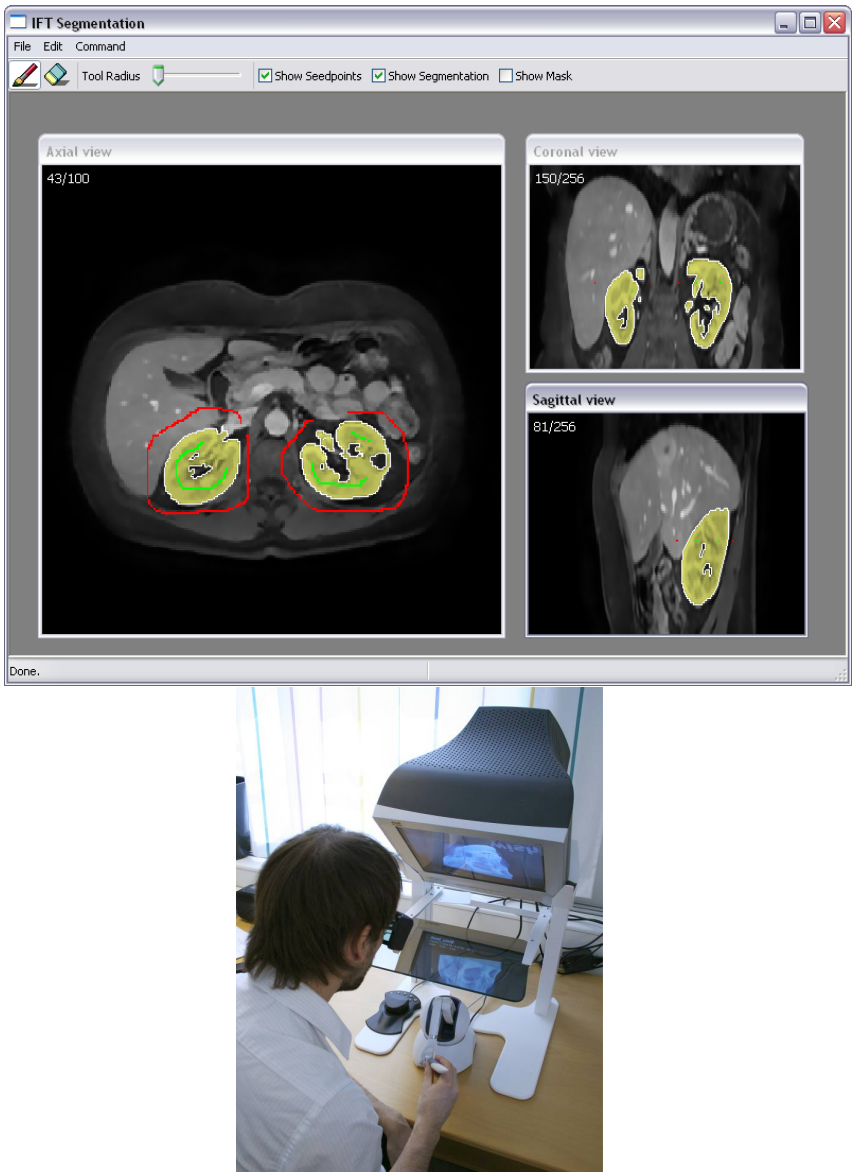


Figure 18: (Top) A user segments organs in a MR volume by placing seed-points representing organ and background, respectively. The segmentation is updated dynamically in real-time. (Bottom) A user working with the haptic display.

45. **Efficient Algorithms for Computer Graphics**
Ewert Bengtsson, Anders Hast
Partner: Tony Barrera, Uppsala
Funding: TN-faculty, UU
Period: 9911–
Abstract: Computer graphics is increasingly being used to create realistic images of 3D objects for applications in entertainment, (animated films, games), commerce (showing 3D images of products on the web), industrial design and medicine. For the images to look realistic high quality shading and surface texture and topology rendering is necessary. A proper understanding of the mathematics behind the algorithms can make a big difference in rendering quality as well as speed. We are in this project re-examining some of the established algorithms and are finding new mathematical ways of simplifying the expressions and increasing the implementation speeds without sacrificing image quality. We have also invented a number of completely new algorithms. The project is carried out in close collaboration with Tony Barrera, an autodidact mathematician. It has been running since 1999 and resulted in more than 25 international publications and a PhD thesis.

46. **CerviScan**
Ewert Bengtsson, Patrik Malm, Hyun-Ju Choi, Bo Nordin
Funding: Swedish Governmental Agency for Innovation Systems (Vinnova) and Swedish Research Council
Period: 0801–
Abstract: Cervical cancer is killing a quarter million women every year. Screening based on so called PAP-smears have proven very effective to reduce cancer mortality but require much work of well trained cytotechnologist. For 50 years research to automate the screening has been in progress, Bengtsson was very active in this field 1973-1993. Since about 10 years, commercial automated systems have been in operation but unfortunately those systems have many limitations.

In India there is no effective screening program in operation and around 70,000 women die from the disease each year. Now an effort to develop a screening system adapted to Indian situation is in progress at the research institute CDAC in Thiruvananthapuram, Kerala in cooperation with the Regional Cancer Centre there. Based on our earlier experience in the field we are cooperating with this project and we have received support from Vinnova and VR for this. We are in particular studying whether the 3D chromatin texture of the cervical cells can be utilized as a robust feature for detecting (pre-) cancerous lesions.

So far we have developed a new approach to segmentation and a method for generating synthesized PAP-smear images which can be used for testing the performance of new segmentation methods, the latter presented at ISBI 2010.

At CDAC they have developed an overall framework for the screening and a program for data collection, they are currently working on improved segmentation and feature extraction methods.

In September 2010 a delegation from CDAC and RCC visited CBA for a workshop where we in detail discussed the progress in the project. That was followed by a visit of Bengtsson to India in late December 2010- early January 2011. During that visit the plans for the continued work on the project were updated.

Dr Hyun-Ju Choi from Korea has studied 3D nuclear texture for other applications and she was a visiting researcher at CBA November 2008 to May 2010, see also Project 47. During that stay she developed texture analysis methods that will be used in this project.

47. **3D Texture Measures for Cell Image Analysis**
Hyun-Ju Choi, Ewert Bengtsson
Funding: Korea Research Foundation and Swedish Research Council
Period: 0811–1005
Abstract: Hyun-Ju Choi was a visiting researcher at CBA 2008-2010. During this time she is developing 3D texture analysis methods. The standard 2D texture analysis methods, GLCM and GLRLM, have been extended and implemented for 3D volume data. New feature sets based on fractal analysis and wavelet transform for describing quantitatively nuclear chromatin changes in 3 dimensions have been developed. The measures have been tested on different data sets and after her return to Korea in May 2010 she has continued working with 3D texture analysis. The plan for the near future is to use the developed methods with image stacks from PAP-smears to detect malignancy related changes.

5.5 Remote Sensing

48. **Surtsey and Capelinhos, Two Contemporary Submarine Volcanoes**
Tommy Lindell
Funding: TN-faculty, UU
Period: 0703–
Abstract: Capelinhos, close to the Island of Faial in the Azores in the middle of the Atlantic, began to erupt on the 27 of September 1957 from 4 submarine vents after a couple of days with seismic activities. The outbreak of magma started a violent eruption of ash, lapilli and steam when it interacted with the sea water. This continued until May 1958. The first two cones collapsed after a few months but the third cone still remains. is located most westerly of the island of Faial.
The island of Surtsey was formed in a volcanic eruption which began 130 meters below sea level, and reached the surface on 14 November 1963. The eruption lasted until 5 June 1967, when the island reached its maximum size of 2.7 km^2. Wind and wave erosion has diminished the island in size to about 1.4 km^2 today. Like as for the Capelinhos, eruptions created more islands from the vents, Jlnir and Syrtlingur but as in the case for Capelinhos those two islands disappeared soon.
Wind and waves are the main factors eroding these two volcanic features. They are now approximately half a century old, resting in two similar locations but within two rather different climatological systems as to their wave and wind climate. One intriguing question is then of course if the environment may have had any major differentiating effect on the present shape of the islands. This is under investigation in this project, based on satellite imagery and aerial photos and climatological data.

49. **Image Analysis for Landscape Analysis**
Anders Brun
Partners: Bo Malmberg, Michael Nielsen, Dept. of Human Geography, Stockholms University; Anders Wästfelt, Dept. of Economics, SLU
Funding: S-faculty, SLU
Period: 0901–
Abstract: This project is a collaboration with researchers at SU and SLU. It aims to derive information about the landscape (rural and city) from satellite images. The project focuses on using textual analysis of images rather than only pixelwise spectral analysis to segment the image into different meaningful regions. One patent application was submitted during 2010.

5.6 Other Projects

50. **DIPimage and DIPlib**
Cris Luengo
Partners: Bernd Rieger, Lucas van Vliet, Quantitative Imaging Group, Delft University of Technology, The Netherlands; Michael van Ginkel, Unilever Research and Development, Colworth House, Bedford, UK
Funding: S-faculty, SLU
Period: 0807–
Abstract: DIPimage is a MATLAB toolbox for scientific image analysis, useful for both teaching and research. It has been in active development since 1999, when it was created at Delft University of Technology. In 2008, when Cris Luengo moved to Uppsala, CBA was added to the project as a main development site. DIPlib, created in 1995, is a C library containing many hundreds of image analysis routines. DIPlib is the core of the DIPimage toolbox, and both projects are developed in parallel. Because DIPlib provides efficient algorithms, MATLAB is useful for image analysis beyond the prototyping stage. Together, MATLAB and DIPimage form a powerful tool for working with scalar and vector images in any number of dimensions.

51. **Animal Rules of Motion**
Cris Luengo
Partners: David Sumpter, Andrea Perna, Daniel Strömbom, Richard Mann, Dept. of Mathematics, UU
Funding: S-faculty, SLU
Period: 0902–
Abstract: Group animals, such as fish, prawns and ants, move based on a set of relatively simple rules. Out of these simple rules, complex group dynamics emerge. Mathematical models, constructed to understand this group behaviour, need to be fitted to observation data. We apply image analysis techniques to automatically obtain position, direction and speed, as well as other movement parameters, from video recordings of such animals in controlled experimental environments.

52. **Tracking Honey Bees and Their Interactions**
Cris Luengo
Partners: Olle Terenius, Ingemar Fries, Joachim Rodrigues de Miranda, Eva Forsgren, Barbara Locke, Dept. of Ecology, SLU; Fredrik Liljeros, Dept. of Sociology, Stockholm University
Funding: Åke Wiberg foundation
Period: 1003–
Abstract: In this project, we intend to set up a system in which we can observe a portion of a bee hive (containing several hundred individuals, each tagged with a number on its back) over days or weeks. Bees will be free to enter and exit the hive, and the environment will be set up to provide them with an environment that is as natural as possible. The purpose is to observe the natural behaviour of the bees, and record the type and duration of interaction between individuals. In 2010 Olle Terenius was awarded a small grant from the Åke Wiberg foundation for materials and consumables, which we will use to create a setup and obtain preliminary data for a larger grant application.

53. **Image Analysis for Studying Horse Behavior**
Anders Brun
Partners: Lars Roepstorff, Anna Byström, SLU
Funding: S-faculty, Dept. of Equine Studies, SLU
Period: 0901–
Abstract: In this project, we track the hoof of the horse, filmed with high-speed cameras, when it

hits the ground after a jump. We also analyze signals from a pressure sensor on the saddle. The work of CBA is mainly to help the veterinary group to analyze these signals. During 2010 we have mainly designed novel algorithms for the analysis of saddle pressure using PCA.

54. **Optical Character Recognition of Handwritten Texts**
Anders Brun, Ewert Bengtsson
Partners: Jonas Lindström Dept. of History; Bengt Dahlqvist Dept. of Linguistics and Philology
Funding: Faculty of Languages and Humanities, UU
Period: 1008–
Abstract: Optical Character Recognition is still, after nearly 100 years of research, an active area of research. Currently one of the frontiers is the recognition of handwritten text, in particular from historical documents. During 2010 the findings of this project were published in a short report about current state-of-the-art algorithms in OCR. Some pilot studies were also performed. The project is now working towards a major grant application to create a centre for handwritten document recognition.

5.7 Cooperation partners

International

School of Information Technology and Electrical Engineering, University of Queensland, Brisbane, Australia

Dept. of anatomy and Histology, Sydney Medical School, University of Sydney, Sydney, Australia

Discipline of Biomedical Sciences, Sydney Medical School, University of Sydney, Sydney, Australia

Ryerson Multimedia Lab, Ryerson University, Toronto, Canada

CSIRO Mathematical and Information Sciences, North Ryde (Sydney), Australia

Risø National Laboratory, Technical University of Denmark, Denmark

Dralle A/S, Copenhagen, Denmark

Visiopharm, Hørsholm, Denmark

Clinical Pathology Division, Vejle hospital, Vejle, Denmark

Dept. of Mathematical Information Technology, University of Jyväskylä, Finland

Dept. of Physics, University of Jyväskylä, Finland

Laboratory of Polymer Technology, Åbo Akademi University, Finland.

Institute for Computational Visualistics, University of Koblenz-Landau, Germany

Dept. of Computer Science, University of Kaiserslautern, Germany

Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary

Dept. of Computer Science, Institute of Informatics, University of Szeged, Hungary

Istituto di Cibernetica, National Research Council, Pozzuoli (Napoli), Italy

School of Computer Engineering, Inje University, Republic of Korea

Ubiquitous Healthcare Research Center, Inje University, Republic of Korea

School of Medicine, Pusan National University, Republic of Korea

Faculty of Applied Sciences, Delft University of Technology, The Netherlands

Faculty of Natural Sciences and Technology, Norwegian University of Science and Technology, Norway

Centre of Mathematics for Applications, University of Oslo, Norway

Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway

SINTEF Materials and Chemistry, Norway

COMSATS, Institute of Information Technology, Islamabad, Pakistan

Faculty of Technical Sciences, University of Novi Sad, Serbia

Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia

University of Peradeniya, Sri Lanka

Ninewells Hospital and Medical School, University of Dundee, Scotland, UK

Unilever Research and Development, Bedford, UK

School of Information and Computer Sciences, University of California, Irvine, CA, USA

Dept. of Systems Biology, Harvard Medical School, Boston, MA, USA

Research Laboratory of Electronics, MIT, Cambridge, USA

Computer Science Division, University of California, Berkeley, CA, USA

Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Oak Ridge National Laboratory, Tennessee, USA

Tech-X Corporation, Colorado, USA

Dept. of Electrical Engineering and Computer Sciences, University of California, USA
Dept. of Computer Science, University of California, USA
Imaging Platform, Broad Institute of Harvard and MIT, MA, USA
Dept. of Ecology and Evolution, The University of Chicago, IL, USA.

National

National Library of Sweden, Stockholm
Nyby Sawmill, Setra Group, Björklinge
Dept. of Mathematics, Natural Sciences, and Computing, University of Gävle, Gävle
SenseGraphics AB, Kista
Centre for Medical Imaging and Visualization, CMIV, Linköping
Dept. of Biomedical Engineering, Linköping University, Linköping
AstraTech, Mölndal
AstraZeneca, Research and Development, Södertälje
Dept. of Science and Technology, Linköping University, Norrköping
Vironova AB, Stockholm
Centre for Microbiological Preparedness, The Swedish Institute for Infectious Disease Control (SMI), Solna
Innventia, Stockholm
Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm
Dept. of Medicine, Division of Cardiology, Karolinska Institute, Stockholm
Dept. of Mathematics, Royal Institute of Technology, Stockholm
Dept. of Human Geography, Stockholms University, Stockholm
Dept. of Sociology, Stockholms University, Stockholm
Industrial Metrology and Optics Group, KTH, Stockholm
Dept. of Fibre and Polymer Technology, KTH, Stockholm
Swedish Timber Measurement Council (VMR), Sundsvall
Dept. of Neurophysiology, Umeå University
Dept. of Genetics and Pathology, UU
Dept. of Information Technology, UU
Dept. of Mathematics, UU
Dept. of Neuroscience, UU
Dept. of Oncology, Radiology, and Clinical Immunology, UU
Dept. of Pharmaceutical Biosciences, UU
Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU
Dept. of Clinical Neuropsychology, UU
Dept. of Psychology, UU
Human-Computer Interaction, UU
Uppsala University Hospital
Dept. of Forest Products, SLU, Uppsala
Department of Equine Studies, SLU, Uppsala
Dept. of Economics, SLU, Uppsala

Dept. of Department of Ecology, SLU, Uppsala

Dept. of Clinical Medicine, Örebro University, Örebro

Imagination Studios, Uppsala

TeknoVest AB, Uppsala

Lantmännen, Lantbruk, Lidköping & Uppsala

Maxx automation AB, Uppsala

GE Healthcare, Uppsala/London

Olink Bioscience, Uppsala

PiezoMotor AB, Uppsala

Protracer AB, Stockholm

Vattenfall Research and Development AB, Stockholm

6 Publications

We consider the publication of our results very important and a measure of the quality of our work. Hence, all research projects we are involved in, see Section 5, should result in one or more publications. Most often we publish in international scientific journals and fully refereed international conference proceedings; this is true for works both on theory and on different applications. In our research field, the impact factor of some of the conferences are in fact higher than well-reputed journals, so in some cases we favour to submit high-quality work to a conference rather than to a journal. In order to meet other scientists, we sometimes publish in non-reviewed conferences, but those results are usually eventually also published elsewhere. We also aim to produce some popular articles, but are less successful in this respect. However, we give a number of such seminars each year.

This list covers all publications with publication date in 2010. We have published a book chapter, 17 journal articles and 14 articles in fully-reviewed international conference proceedings. In addition, we published 15 papers in workshops, non-refereed or abstract refereed conference proceedings and two other reports. The number of publications from CBA between 1997-2010 are shown in Figure 19.

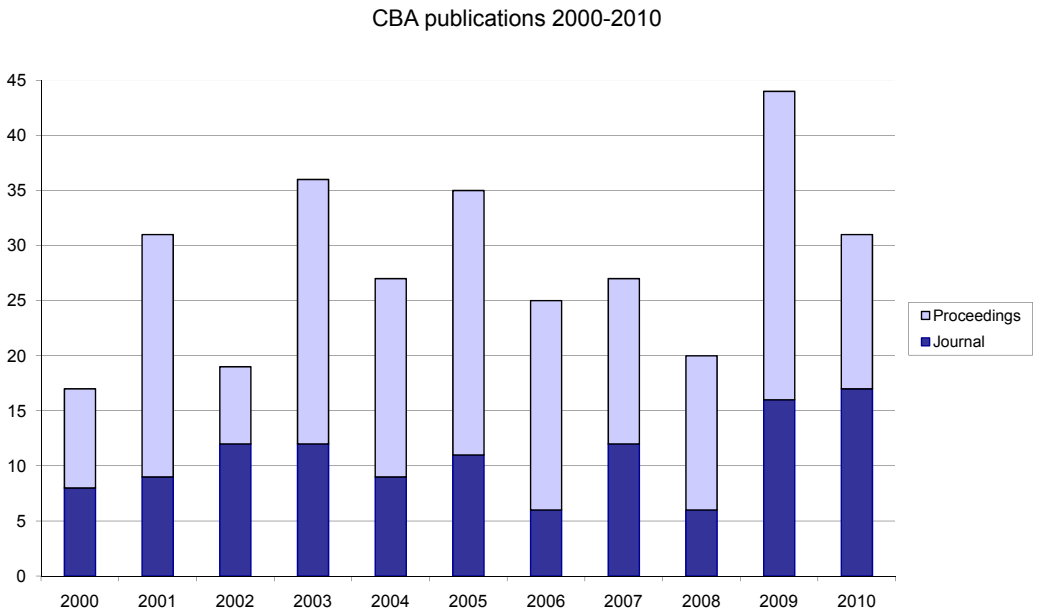


Figure 19: The number of publications from CBA.

6.1 Book chapters

1. **3D Stereoscopic Rendering : An Overview of Implementation Issues**
   Author: **Anders Hast**
   Book: Game Engine Gems, pp. 123–138
   Publisher: Jones and Bartlett Learning

6.2 Journal articles

1. **The Effect of Drugs With Ion Channel-Blocking Activity on the Early Embryonic Rat Heart**
   Authors: Dominique Abela(1), Helen Ritchie(2), Deena Ababneh(1), Caroline Gavin(1), Mats F. Nilsson(3), **Muhammad Khalid Khan**, Kristin Carlsson(1), and William S. Webster(1)
   (1) Dept. of Anatomy and Histology, Sydney Medical School, University of Sydney, Sydney, Australia
   (2) Discipline of Biomedical Sciences, Sydney Medical School, University of Sydney, Sydney, Australia
   (3) Dept. of Pharmaceutical Biosciences, Division of Toxicology, Uppsala University
   Journal: Birth defects research. Part B. Developmental and reproductice toxicology 89(5), pp. 429–440
   Abstract: This study investigated the effects of a range of pharmaceutical drugs with ion channel-blocking activity on the heart of gestation day 13 rat embryos in vitro. The general hypothesis was that the blockade of the I-Kr/hERG channel, that is highly important for the normal functioning of the embryonic rat heart, would cause bradycardia and arrhythmia. Concomitant blockade of other channels was expected to modify the effects of hERG blockade. Fourteen drugs with varying degrees of specificity and affinity toward potassium, sodium, and calcium channels were tested over a range of concentrations. The rat embryos were maintained for 2 hr in culture, 1 hr to acclimatize, and 1 hr to test the effect of the drug. All the drugs caused a concentration-dependent bradycardia except nifedipine, which primarily caused a negative inotropic effect eventually stopping the heart. A number of drugs induced arrhythmias and these appeared to be related to either sodium channel blockade, which resulted in a double atrial beat for each ventricular beat, or IKr/hERG blockade, which caused irregular atrial and ventricular beats. However, it is difficult to make a precise prediction of the effect of a drug on the embryonic heart just by looking at the polypharmacological action on ion channels. The results indicate that the use of the tested drugs during pregnancy could potentially damage the embryo by causing periods of hypoxia. In general, the effects on the embryonic heart were only seen at concentrations greater than those likely to occur with normal therapeutic dosing.

2. **Robust Signal Detection in 3D Fluorescence Microscopy**
   Authors: **Amin Allalou**, **Amalka Pinidiyaarachchi**, **Carolina Wählby**
   Journal: Cytometry. Part A, 77A, pp. 86–96
   Abstract: Robust detection and localization of biomolecules inside cells is of great importance to better understand the functions related to them. Fluorescence microscopy and specific staining methods make biomolecules appear as point-like signals on image data, often acquired in 3D. Visual detection of such point-like signals can be time consuming and problematic if the 3D images are large, containing many, sometimes overlapping, signals. This sets a demand for robust automated methods for accurate detection of signals in 3D fluorescence microscopy. We propose a new 3D point-source signal detection method that is based on Fourier series. The method consists of two parts, a detector, which is a cosine filter to enhance the point-like signals, and a verifier, which is a sine filter to validate the result from the detector. Compared to conventional methods, our method shows better robustness to noise and good ability to resolve signals that are spatially close. Tests on image data show that the method has equivalent accuracy in signal detection in comparison to Visual detection by experts. The proposed method can be used as an efficient point-like signal detection tool for various types of biological 3D image data.

3. **3D pore structure characterisation of paper**
   Authors: **Maria Axelsson**, **Stina Svensson**
   Journal: Pattern Analysis and Applications, 13(2), pp. 159–172
   Abstract: Pore structure characterisation of paper, using automated image analysis methods, has previously been performed in two-dimensional images. Three dimensional (3D) images have become available and thereby new representations and corresponding measurements are needed for 3D pore structure characterisation. In this article, we present a new pore structure representation, the individual pore-based skeleton, and new quantitative measurements for individual pores in 3D, such as surface area, orientation, anisotropy,

and size distributions. We also present measurements for network relations, like tortuosity and connectivity. The data used to illustrate the pore structure representations and corresponding measurements are high resolution X-ray microtomography volume images of a layered duplex board imaged at the European Synchrotron Radiation Facility (ESRF). Quantification of the pore structure is exemplified and the results show that differences in pore structure between the layers in the cardboard can be characterised using the presented methods.

4. **Effects of Aging and Gender on the Spatial Organization of Nuclei in Single Human Skeletal Muscle Cells**
   Authors: Alexander Cristea(1), Rizwan Qaisar(1), **Patrick Karlsson Edlund**, **Joakim Lindblad**, **Ewert Bengtsson**, Lars Larsson(1)
   (1) UU, Dept. of Clinical Neurophysiology
   Journal: Aging Cell, 9(5), pp. 685–697
   Abstract: The skeletal muscle fibre is a syncitium where each myonucleus regulates the gene products in a finite volume of the cytoplasm, i.e., the myonuclear domain (MND). We analysed aging- and gender-related effects on myonuclei organization and the MND size in single muscle fibres from six young (21–31 years) and nine old men (72–96 years), and from six young (24–32 years) and nine old women (65–96 years), using a novel image analysis algorithm applied to confocal images. Muscle fibres were classified according to myosin heavy chain (MyHC) isoform expression. Our image analysis algorithm was effective in determining the spatial organization of myonuclei and the distribution of individual MNDs along the single fibre segments. Significant linear relations were observed between MND size and fibre size, irrespective age, gender and MyHC isoform expression. The spatial organization of individual myonuclei, calculated as the distribution of nearest neighbour distances in 3D, and MND size were affected in old age, but changes were dependent on MyHC isoform expression. In type I muscle fibres, average NN-values were lower and showed an increased variability in old age, reflecting an aggregation of myonuclei in old age. Average MND size did not change in old age, but there was an increased MND size variability. In type IIa fibres, average NN-values and MND sizes were lower in old age, reflecting the smaller size of these muscle fibres in old age. It is suggested that these changes have a significant impact on protein synthesis and degradation during the aging process.

5. **Signal Extraction and Separation in In Vivo Animal PET Studies with Masked Volumewise Principal-Component Analysis**
   Authors: Fredrik Engbrant(1), Azita Monazzam(1), Per-Edvin Svensson(1), Johan Olsson(1), **Ewert Bengtsson**, Pasha Razifar(1)
   (1) Uppsala Applied Science Laboratory (UASL), GE Healthcare, Uppsala, Sweden
   Journal: Nuclear Medicine Technology, 38(2), pp. 53–60
   Abstract: The standardized uptake value is commonly used as a tool to supplement visual interpretation and to quantify the images acquired from static in vivo animal PET. The preferred approach for analyzing PET data is either to sum the images and calculate the standardized uptake value or to use kinetic modeling. The aim of this study was to investigate the performance of masked volumewise principal-component analysis (MVW-PCA) used in dynamic in vivo animal PET studies to extract and separate signals with different kinetic behaviors. Methods: PET data were acquired with a small-animal PET scanner and a fluorine tracer in a study of rats and mice. After acquisition, the data were reconstructed by use of 4 time protocols with different frame lengths. Data were analyzed by use of MVW-PCA with applied noise prenormalization and a new masking technique developed in this study. Results: The resulting principal-component images showed a clear separation of the activity in the spine into the first MVW-PCA component and the activity in the kidneys into the second MVW-PCA component. In addition, the different time protocols were shown to have little or no impact on the results obtained with MVW-PCA. Conclusion: MVW-PCA can efficiently separate different kinetic behaviors into different principal-component images. Moreover, MVW-PCA is a stable technique in the sense that the time protocol chosen has only a small impact on the resulting principal-component images.

6. **Image Processing System for Localising Macromolecules in Cryo-Electron Tomography**
   Authors: **Magnus Gedda**, L.-G. Öfverstedt(1), U. Skoglund(1), **Stina Svensson**
   (1) Okinawa Institute of Science and Technology, Japan
   Journal: Machine Graphics & Vision, 19(2), pp. 159–184
   Abstract: A major challenge in today's molecular biology research is to understand the interaction between

proteins at the molecular level. Cryo-electron tomography (ET) has come to play an important role in facilitating objective qualitative experiments on protein structures and their interaction. Various protein conformation structures can be qualitatively analysed as complete galleries of proteins are captured by ET. To facilitate fast and objective macromolecular structure analysis procedures, image processing has become a crucial tool. This paper presents an image processing system for localising individual proteins from in vitro samples imaged by ET. We have evaluated the system using simulated data as well as experimental data.

7. **Velocity and Pressure-based Partitions of Horizontal and Vertical Trajectories for On-line Signature Verification**
   Authors: Muhammad Talal Ibrahim(1), M. Aurangzeb Khan(2), Khurram Saleem Alimgeer(2), **Muhammad Khalid Khan**, Imtiaz A. Taj(3), Ling Guan(1)
   (1) Ryerson Multimedia Research Lab, Ryerson University, Toronto, Canada
   (2) Dept. of Electrical Engineering, COMSATS Institute of Information Technology, Islamabad, Pakistan
   (3) Dept. of Electronics Engineering, Mohammad Ali Jinnah University, Islamabad, Pakistan
   Journal: Pattern Recognition 43(8), pp. 2817–2832
   Abstract: In general, shape of an on-line signature is used as a single discriminating feature. Sometimes shape of signature is used alone for verification purposes and sometimes it is used in combination with some other dynamic features such as velocity, pressure and acceleration. The shape of an on-line signature is basically formed due to the wrist and fingers movements where the wrist movement is represented by the horizontal trajectory and the movement of the fingers is represented by vertical trajectory. As the on-line signature is formed due to the combination of two movements that are essentially independent of each other, it will be more effective to use them as two separate discriminating features. Based on this observation, we propose to use these trajectories in isolation by first decomposing the pressure and velocity profiles into two partitions and then extracting the underlying horizontal and vertical trajectories. So the overall process can be thought as the process which exploits the inter-feature dependencies by decomposing signature trajectories depending upon pressure and velocity information and performs verification on each partition separately. As a result, we are able to extract eight discriminating features and among them the most stable discriminating feature is used in verification process. Further Principal Component Analysis (PCA) has been proposed to make the signatures rotation invariant. Experimental results demonstrate superiority of our approach in on-line signature verification in comparison with other techniques.

8. **Three-dimensional Texture Analysis of Renal Cell Carcinoma Cell Nuclei for Computerized Automatic Grading**
   Authors: Tae-Yun Kim(1), **Hyun-Ju Choi**, Hae-Gil Hwang(1), Heung-Kook Choi(2)
   (1) School of computer engineering, Inje University, Korea
   (2) Ubiquitous Healthcare Research Center, Inje University, Korea
   Journal: Journal of medical systems, 34(4), pp. 709–716
   Abstract: The extraction of important features in cancer cell image analysis is a key process in grading renal cell carcinoma. In this study, we analyzed the three-dimensional chromatin texture of cell nuclei based on digital image cytometry. Individual images of 2,423 cell nuclei were extracted from 80 renal cell carcinomas (RCCs) using confocal laser scanning microscopy (CLSM). First, we applied the 3D texture mapping method to render the volume of entire tissue sections. Then, we determined the chromatin texture quantitatively by calculating 3D gray level co-occurrence matrices and 3D run length matrices. Finally, to demonstrate the suitability of 3D texture features for classification, we performed a discriminant analysis. In addition, we conducted a principal component analysis to obtain optimized texture features. Automatic grading of cell nuclei using 3D texture features had an accuracy of 78.30%. Combining 3D textural and 3D morphological features improved the accuracy to 82.19%.

9. **Evaluating 2D and 3D Visualizations of Spatiotemporal Information**
   Authors: Andreas Kjellin(1), Lars Winkler Pettersson(1), **Stefan Seipel**, Mats Lind(1)
   (1) UU Human-Computer Interaction
   Journal: ACM Transactions on Applied Perception 7(3), pp. 1–23
   Abstract: Time-varying geospatial data presents some specific challenges for visualization. Here, we report the results of three experiments aiming at evaluating the relative efficiency of three existing visualization techniques for a class of such data. The class chosen was that of object movement, especially the movements of vehicles in a fictitious landscape. Two different tasks were also chosen. One was to predict where three

vehicles will meet in the future given a visualization of their past movement history. The second task was to estimate the order in which four vehicles arrived at a specific place. Our results reveal that previous findings had generalized human perception in these situations and that large differences in user efficiency exist for a given task between different types of visualizations depicting the same data. Furthermore, our results are in line with earlier general findings on the nature of human perception of both object shape and scene changes. Finally, the need for new taxonomies of data and tasks based on results from perception research is discussed.

10. **Different Levels of 3D: An Evaluation of Visualized Discrete Spatiotemporal Data in Space-time Cubes**
    Authors: Andreas Kjellin(1), Lars Winkler Pettersson(1), **Stefan Seipel**, Mats Lind(1)
    (1) UU Human-Computer Interaction
    Journal: Information Visualization, 9(2), pp. 152–164
    Abstract: New technologies and techniques allow novel kinds of visualizations and different types of 3D visualizations are constantly developed. We propose a categorization of 3D visualizations and, based on this categorization, evaluate two versions of a space-time cube that show discrete spatiotemporal data. The two visualization techniques used are a head-tracked stereoscopic visualization ('strong 3D') and a static monocular visualization ('weak 3D'). In terms of effectiveness and efficiency the weak 3D visualization is as good as the strong 3D and thus the need for advanced 3D visualizations in these kinds of tasks may not be necessary.

11. **Revisiting Priority Queues for Image Analysis**
    Author: **Cris L. Luengo Hendriks**
    Journal: Pattern Recognition, 43(9), pp. 3003–3012
    Abstract: Many algorithms in image analysis require a priority queue, a data structure that holds pointers to pixels in the image, and which allows efficiently finding the pixel in the queue with the highest priority. However, very few articles describing such image analysis algorithms specify which implementation of the priority queue was used. Many assessments of priority queues can be found in the literature, but mostly in the context of numerical simulation rather than image analysis. Furthermore, due to the ever-changing characteristics of computing hardware, performance evaluated empirically 10 years ago is no longer relevant. In this paper I revisit priority queues as used in image analysis routines, evaluate their performance in a very general setting, and come to a very different conclusion than other authors: implicit heaps are the most efficient priority queues. At the same time, I propose a simple modification of the hierarchical queue (or bucket queue) that is more efficient than the implicit heap for extremely large queues.

12. **Constrained and Dimensionality-Independent Path Opening**
    Author: **Cris L. Luengo Hendriks**
    Journal: IEEE Transactions on Image Processing 19(6), pp. 1587–1595
    Abstract: Path openings and closings are morphological operations with flexible line segments as structuring elements. These line segments have the ability to adapt to local image structures, and can be used to detect lines that are not perfectly straight. They also are a convenient and efficient alternative to straight line segments as structuring elements when the exact orientation of lines in the image is not known. These path operations are defined by an adjacency relation, which typically allows for lines that are approximately horizontal, vertical or diagonal. However, because this definition allows zig-zag lines, diagonal paths can be much shorter than the corresponding horizontal or vertical paths. This undoubtedly causes problems when attempting to use path operations for length measurements. This paper 1) introduces a dimensionality-independent implementation of the path opening and closing algorithm by Appleton and Talbot, 2) proposes a constraint on the path operations to improve their ability to perform length measurements, and 3) shows how to use path openings and closings in a granulometry to obtain the length distribution of elongated structures directly from a gray-value image, without a need for binarizing the image and identifying individual objects.

13. **Improved Methodology for Identifying the Teratogenic Potential in Early Drug Development of hERG Channel Blocking Drugs**
    Authors: M. F. Nilsson(1), C. Danielsson(2), A.-C. Sköld(3), A. Johansson (3), B. Blomgren(3), J. Wilson(3), **K.M. Khan**, **E. Bengtsson**, K. Kultima(1,4), W.S. Webster(5), B.R. Danielsson(1)
    (1) Dept. of Pharmaceutical Biosciences, Division of Toxicology, Uppsala University, Sweden
    (2) Dept. of Medicine H7, Division of Cardiology, Karolinska University Hospital, Stockholm, Sweden

(3) AstraZeneca R&D Södertälje, Safety Assessment, Södertälje, Sweden
(4) Dept. on Medical Sciences, Cancer Pharmacology and Informatics, Uppsala University Hospital
(5) Dept. of Anatomy and Histology, University of Sydney, NSW 2006, Australia
Journal: Reproductive Toxicology 29(2), pp. 156–163
Abstract: Drugs blocking the potassium current IKr of the heart (via hERG channel-inhibition) have the potential to cause hypoxia-related teratogenic effects. However, this activity may be missed in conventional teratology studies because repeat dosing may cause resorptions. The aim of the present study was to investigate an alternative protocol to reveal the teratogenic potential of IKr-blocking drugs. The IKr blocker astemizole, given as a single dose (80mg/kg) on gestation day (GD) 13 to pregnant rats caused digital defects. In whole rat embryo culture (2h) on GD 13, astemizole caused a decrease in embryonic heart rate at 20nM, and arrhythmias at 200-400nM. Cetirizine, without IKr-blocking properties, did not affect the rat embryonic heart in vitro. The present study shows that single dose testing on sensitive days of development, together with whole embryo culture, can be a useful methodology to better characterize the teratogenic potential of IKr-blocking drugs.

14. **Integrating Data Clustering and Visualizationfor the Analysis of 3D Gene Expression Data**
Authors: Oliver Rbel(1), Gunther H. Weber(1), Min-YuHuang(2), E. Wes Bethel(1), Mark D. Biggin(1), Charless C. Fowlkes(3), **Cris L. Luengo Hendriks**, Soile V.E. Keränen(1), Michael B. Eisen(4), David W. Knowles(1), Jitendra Malik(4) and Bernd Hamann(2)
(1) Lawrence Berkeley National Laboratory
(2) University of California, Davis
(3) University of California, Irvine
(4) University of California, Berkeley
Journal: IEEE/ACM Transactions on Computational Biology & Bioinformatics 7(1), pp. 64–69
Abstract: The recent development of methods for extracting precise measurements of spatial gene expression patterns from three-dimensional (3D) image data opens the way for new analyses of the complex gene regulatory networks controlling animal development. We present an integrated visualization and analysis framework that supports user-guided data clustering to aid exploration of these new complex data sets. The interplay of data visualization and clustering-based data classification leads to improved visualization and enables a more detailed analysis than previously possible. We discuss 1) the integration of data clustering and visualization into one framework, 2) the application of data clustering to 3D gene expression data, 3) the evaluation of the number of clusters k in the context of 3D gene expression clustering, and 4) the improvement of overall analysis quality via dedicated postprocessing of clustering results based on visualization. We discuss the use of this framework to objectively define spatial pattern boundaries and temporal profiles of genes and to analyze how mRNA patterns are controlled by their regulatory transcription factors.

15. **Gradient Based Intensity Normalization**
Authors: **Ida-Maria Sintorn**, Leanne Bischof(1), Michael Buckley(1), Paul Jackway(1), Stephen Haggarty(2)
(1) CSIRO Mathematical and Information Sciences
(2) BROAD Institute of Harvard and MIT
Journal: Journal of Microscopy, 3, pp. 249–258
Abstract: Intensity normalization is important in quantitative image analysis, especially when extracting features based on intensity. In automated microscopy, particularly in large cellular screening experiments, each image contains objects of similar type (e.g. cells) but the object density (number and size of the objects) may vary markedly from image to image. Standard intensity normalization methods, such as matching the grey-value histogram of an image to a target histogram from, i.e. a reference image, only work well if both object type and object density are similar in the images to be matched. This is typically not the case in cellular screening and many other types of images where object type varies little from image to image, but object density may vary dramatically. In this paper, we propose an improved form of intensity normalization which uses grey-value as well as gradient information. This method is very robust to differences in object density. We compare and contrast our method with standard histogram normalization across a range of image types, and show that the modified procedure performs much better when object density varies between images.

16. **On the Role of Visual References in Collaborative Visualization**
Authors: Lars Winkler Pettersson(1), Andreas Kjellin(1), Mats Lind(1), **Stefan Seipel**
(1) Uppsala University, Human-Computer Interaction
Journal: Information Visualization, 9(2), pp. 98–114
Abstract: Multi-Viewer Display Environments (MVDE) provide unique opportunities to present personalized information to several users concurrently in the same physical display space. MVDEs can support correct 3D visualizations to multiple users, present correctly oriented text and symbols to all viewers and allow individually chosen subsets of information in a shared context. MVDEs aim at supporting collaborative visual analysis, and when used to visualize disjoint information in partitioned visualizations they even necessitate collaboration. When solving visual tasks collaboratively in a MVDE, overall performance is affected not only by the inherent effects of the graphical presentation but also by the interaction between the collaborating users. We present results from an empirical study where we compared views with lack of shared visual references in disjoint sets of information to views with mutually shared information. Potential benefits of 2D and 3D visualizations in a collaborative task were investigated and the effects of partitioning visualizations both in terms of task performance, interaction behavior and clutter reduction. In our study of a collaborative task that required only a minimum of information to be shared, we found that partitioned views with a lack of shared visual references were significantly less efficient than integrated views. However, the study showed that subjects were equally capable of solving the task at low error levels in partitioned and integrated views. An explorative analysis revealed that the amount of visual clutter was reduced heavily in partitioned visualization, whereas verbal and deictic communication between subjects increased. It also showed that the type of the visualization (2D/3D) affects interaction behavior strongly. An interesting result is that collaboration on complex geo-time visualizations is actually as efficient in 2D as in 3D.

17. **Bright-Field Microscopy Visualization of Proteins and Protein Complexes by In Situ Proximity Ligation with Peroxidase Detection**
Authors: Agata Zieba(1), **Carolina Wählby**, Fredrik Hjelm(2), Lee Jordan(3), Jonathan Berg(3), Ulf Landegren(1), Katerina Pardali(1)
(1) Dept. of Genetics and Pathology, UU
(2) Olink Bioscience, Uppsala
(3) Ninewells Hospital and Medical School, University of Dundee, Scotland, UK
Journal: Clinical Chemistry, 56(1), pp. 99–110
Abstract: BACKGROUND: The in situ proximity ligation assay (PLA) allows a protein or protein complex to be represented as an amplifiable DNA molecule. Recognition is mediated by proximity probes consisting of antibodies coupled with oligonucleotides. Upon dual binding of the proximity probes, the oligonucleotides direct the formation of a circular DNA molecule, which is then amplified by rolling-circle replication. The localized concatemeric product is then detected with fluorescent probes. The in situ PLA enables localized detection of individual native proteins or interacting protein pairs in fixed cells or tissue sections, thus providing an important tool for basic and clinical research.

METHODS: We used horseradish peroxidase (HRP)conjugated oligonucleotides to couple in situ PLA with enzymatic visualization of the localized detection event.

RESULTS: We demonstrate the detection of protein complexes, both in cells and in tissue sections, and show that we can quantify the complexes with image-analysis software specially developed for recognizing HRP signals in bright-field microscopy images. We show that fluorescence and HRP signals produce equivalent results, both ill cultured cells and in tissue samples.

CONCLUSIONS: The combination of in situ PLA with bright-field detection and automated image analysis allows the signals present to be Counted in an automated fashion and thus provides a sensitive and specific method for quantification of proteins and protein complexes with bright-field microscopy. With this approach, in situ PLA can be used without the requirement for expensive fluorescence microscopes, thereby avoiding problems with nonspecific fluorescence while maintaining compatibility with conventional histologic staining.

6.3 Refereed conference proceedings

1. **Recognizing signs of malignancy: The quest for computer assisted cancer screening and diagnosis systems**
   Authors: **Ewert Bengtsson**
   Conference: IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), 2010, Coimbatore, India, December 28-29, pp. 1–6
   Publisher: IEEE Computer Society
   Abstract: Almost all cancers are diagnosed through visual examination of microscopic tissue samples. Visual screening of cell samples, so called PAP-smears, has drastically reduced the incidence of cervical cancers in countries that have implemented population wide screening programs. But the visual examination is tedious, subjective and expensive. There has therefore been much research aiming for computer assisted or automated cell image analysis systems for cancer detection and diagnosis. Progress has been made but still most of cytology and pathology is done visually. In this presentation I will discuss some of the major issues involved, examine some of the proposed solutions and give some comments about the state of the art.

2. **Three-Dimensional Tracing of Neurites in Fluorescence Microscopy Images Using Local Path-Finding**
   Authors: **Magnus Gedda** and Pascal Vallotton(1)
   (1) CSIRO Mathematical and Information Sciences, Sydney, Australia
   Conference: IEEE International Conference On Acoustics, Speech And Signal Processing (ICASSP), Dallas, Texas, USA, March 14-19, pp. 646–649
   Publisher: IEEE Computer Society
   Abstract: Neurite tracing in 3D neuron images is important when it comes to analysing the growth and functionality of nerve cells. The methods used today are either of high complexity, limiting throughput, or semi-automatic, i.e., requiring user interaction. This makes them unsuitable for analysis where high throughput is needed. In this work we propose a method designed for low complexity and void of user interaction by using local path-finding. The method is illustrated on both phantom and real data, and compared with a widely used commercial software package with promising results.

3. **A Cost-Efficient and Automatic Digitization Workflow Using Commodity Hardware and Image Analysis**
   Authors: Henrik Johansson(1), Per Erik Svedlund(1), Erik Siira(1), **Hamid Sarve**
   (1) National Library of Sweden
   Conference: Archiving, Den Haag, The Netherlands, June 1-4, pp. 101–106
   Publisher: Society for Imaging Science and Technology
   Abstract: Digitization projects put large strains on organizations with limited financial resources. Dedicated digitization equipment is expensive, both to acquire and to maintain. Furthermore, a significant workforce is needed to operate the equipment and to perform necessary post-processing tasks. To achieve high digitization throughput with limited resources, both the cost of the digitization equipment and the amount of manual labour must be reduced.

   In this paper, we present the digitization equipment and the digitization workflow at the National Library of Sweden (Kungliga Biblioteket, the KB). The workflow is designed towards a single goal; to achieve the highest possible digitization throughput using the least amount of resources – without any significant loss of quality or risk of compromising delicate objects.

   For the image capture, we use a commodity DSLRs, the Canon 5D Mark II. To make the image capture more efficient, the labour intensive and error-prone tasks of organizing and renaming the image files are automatically performed by in-house software.

   During post-processing, we derive files suitable for presentation. For the presentation files, we remove excess areas around the object and we color correct, resize and sharpen the images. These tasks are time-consuming to perform manually. Hence, we have developed an in-house application to automatically perform the post-processing with minimal input from the operator.

   With the presented workflow, involving commodity hardware and extensive use of in-house software, we have been able to more than triple our digitization throughput despite limited financial resources. The pending use of edge-detection, image matching, and distributed computing will further increase the throughput without the need of additional resources.

4. **De-noising of SRμCT Fiber Images by Total Variation Minimization**
   Authors: **Joakim Lindblad**, Nataša Sladoje(1), Tibor Lukic(1)
   (1) University of Novi Sad, Faculty of Engineering
   Conference: 20th International Conference on Pattern Recognition (ICPR), Istanbul, Turkey, August 23-26, pp. 4621–4624
   Publisher: IEEE Computer Society
   Abstract: SRμCT images of paper and pulp fiber materials are characterized by a low signal to noise ratio. De-noising is therefore a common preprocessing step before segmentation into fiber and background components. We suggest a de-noising method based on total variation minimization using a modified Spectral Conjugate Gradient algorithm. Quantitative evaluation performed on synthetic 3D data and qualitative evaluation on real 3D paper fiber data confirm appropriateness of the suggested method for the particular application.

5. **PAPSYNTH: Simulated Bright-Field Images of Cervical Smears**
   Authors: **Patrik Malm**, **Anders Brun**, **Ewert Bengtsson**
   Conference: IEEE International Symposium on Biomedical Imaging: From Nano to Macro (ISBI), Rotterdam, The Netherlands, April 14-17, pp. 117–120
   Publisher: IEEE Computer Society
   Abstract: In this paper, we present a simulator for bright-field microscope images of "Pap-smears", which is the most common technique used today for cervical cancer screening. Lacking a ground truth for real images, these realistic synthetic images may be used to tune and validate image analysis and processing algorithms. We demonstrate this for two tasks: uncorrelated noise removal and nucleus segmentation. The simulator is a part of a larger project, aiming at automatic, cost efficient screening for cervical cancer in developing countries.

6. **Two Non-linear Parametric Models of Contrast Enhancement for DCE-MRI of the Breast Amenable to Fitting Using Linear Least Squares**
   Author: Andrew Mehnert(1), Michael Wildermoth(1), Stuart Crozier(1), **Ewert Bengtsson**, Dominic Kennedy(2)
   (1) School of ITEE, University of Queensland, Australia
   (2) Queensland X-Ray, Greenslopes Private Hospital, Australia
   Conference: International Conference on Digital Image Computing: Techniques and Applications (DICTA), Sydney, Australia, December 1-3, pp. 611–616
   Publisher: IEEE Computer Society
   Abstract: This paper proffers two non-linear empirical parametric models–linear slope and Ricker–for use in characterising contrast enhancement in dynamic contrast enhanced (DCE) MRI. The advantage of these models over existing empirical parametric and pharmacokinetic models is that they can be fitted using linear least squares (LS). This means that fitting is quick, there is no need to specify initial parameter estimates, and there are no convergence issues. Furthermore the LS fit can itself be used to provide initial parameter estimates for a subsequent NLS fit (self-starting models). The results of an empirical evaluation of the goodness of fit (GoF) of these two models, measured in terms of both MSE and R^2, relative to a two-compartment pharmacokinetic model and the Hayton model are also presented. The GoF was evaluated using both routine clinical breast MRI data and a single high temporal resolution breast MRI data set. The results demonstrate that the linear slope model fits the routine clinical data better than any of the other models and that the two parameter self-starting Ricker model fits the data nearly as well as the three parameter Hayton model. This is also demonstrated by the results for the high temporal data and for several temporally sub-sampled versions of this data.

7. **A Modified Particle Swarm Optimization Applied in Image Registration**
   Author: **Muhammad Khalid Khan Niazi**, **Ingela Nyström**
   Conference: 20th International Conference on Pattern Recognition (ICPR), Istanbul, Turkey, August 23-26, pp. 2303–2305
   Publisher: IEEE Computer Society
   Abstract: We report a modified version of the particle swarm optimization (PSO) algorithm and its application to image registration. The modified version utilizes benefits from the Gaussian and the uniform distribution, when updating the velocity equation in the PSO algorithm. Which one of the distributions is selected depends on the direction of the cognitive and social components in the velocity equation. This direction checking and selection of the appropriate distribution provide the particles with an ability to jump

out of local minima. The registration results achieved by this new version proves the robustness and its ability to find a global minimum.

8. **Coupling Visualization and Data Analysis for Knowledge Discovery from Multi-dimensional Scientific Data**
Authors: Oliver Rbel(1), Sean Ahern(2), Bethel, E. Wes(1), Biggin, Mark D.(1), Childs, Hank(1), Estelle, Cormier-Michel(3), Angela, DePace(4), Michael B. Eisen(5), Charless C. Fowlkes(6), Cameron G.R. Geddes(1), Hans Hagen(7), Bernd Hamann(1), Min-Yu Huang(8), Soile V.E. Keränen(1), David W. Knowles(1), **Cris L. Luengo Hendriks**, Jitendra Malik(5), Jeremy Meredith(2), Peter Messmer(3), Prabhat(1), Daniela Ushizima(1), Gunther H. Weber(1) and Kesheng Wu(1)
(1) Lawrence Berkeley National Laboratory, California
(2) Oak Ridge National Laboratory, Tennessee
(3) Tech-X Corporation, Colorado
(4) Harvard Medical School, Massachusetts
(5) University of California, Berkeley
(6) University of California, Irvine
(7) University of Kaiserslautern, Germany
(8) University of California, Davis
Conference: International Conference on Computational Science (ICCS), Amsterdam, The Netherlands, May 31-June 2
Procedia Computer Science, 1(1), pp. 1751–1758
Publisher: Elsevier
Abstract: Knowledge discovery from large and complex scientific data is a challenging task. With the ability to measure and simulate more processes at increasingly finer spatial and temporal scales, the growing number of data dimensions and data objects presents tremendous challenges for effective data analysis and data exploration methods and tools. The combination and close integration of methods from scientific visualization, information visualization, automated data analysis, and other enabling technologies – such as efficient data management – supports knowledge discovery from multi-dimensional scientific data. This paper surveys two distinct applications in developmental biology and accelerator physics, illustrating the effectiveness of the described approach.

9. **Methods for Visualization of Bone Tissue in the Proximity of Implants**
Authors: **Hamid Sarve**, **Joakim Lindblad**, Carina Johansson(1), **Gunilla Borgefors**
(1) Örebro University
Conference: International Conference on Computer Vision and Graphics (ICCVG), Warsaw, Poland, September 20-22
Lecture Notes in Computer Science (LNCS) 6375, pp. 243–250
Editors: L. Bolc, R. Tadeusiewicz, L.J. Chmielewski, K. Wojciechowski
Publisher: Springer-Verlag Berlin, Heidelberg
Abstract: In this work we present two methods for visualization ofSRμCT-scanned 3D volumes of screw-shaped bone implant samples:thread fly-through and 2D unfolding. The thread fly-through generates an animation by following the thread helix and extracting slices along it. Relevant features, such as bone ratio and bone implant contact, are computed for each slice of the animation and displayed as graphs beside the animation. The 2D unfolding, on the other hand, maps the implantsurface onto which feature information is projected to a 2D image, providing an instant overview of the whole implant. The unfolding is made area-preserving when appropriate. These visualization methods facilitate better understanding of the bone-implant integration and provides a good platform for communication between involved experts.

10. **A Local Curvature Based Lighting Model for Rendering of Snow**
Authors: **Stefan Seipel** and **Anders Hast**
Conference: IADIS Computer Graphics, Visualization, Computer Vision and Image Processing Conference (CGVCVIP), Freiburg, Germany, July 27-29, pp. 367–372
Publisher: International Association for Development of the Information Society
Comment: Short paper
Abstract: Local illumination models try to describe the interaction between light and objects in the scene based on only few parameters representing some geometric and material properties at a given point on a surface. In this paper we present our research in local illumination models for the purpose of approximating

light transport and shadow-masking effects in the local neighborhood of the surface point under evaluation. We assume that the amount of curvature at a surface point to some extent represents geometric properties in the surrounding neighborhood of this point. From this we define an empirical illumination model for diffuse reflecting materials which controls the amount of locally scattered light from the neighborhood as well as subsurface light transport based on some curvature metric.

11. **Sampling and Ideal Reconstruction on the 3D Diamond Grid**
Author: **Robin Strand**
Conference: 20th International Conference on Pattern Recognition (ICPR), Istanbul, Turkey, August 23-26, pp. 4609–4612
Publisher: IEEE Computer Society
Abstract: This paper presents basic, yet important, properties that can be used when developing methods for image acquisition, processing, and visualization on the diamond grid. The sampling density needed to reconstruct a band-limited signal and the ideal interpolation function on the diamond grid are derived.

12. **Interpolation and Sampling on a Honeycomb Lattice**
Author: **Robin Strand**
Conference: 20th International Conference on Pattern Recognition (ICPR), Istanbul, Turkey, August 23-26, pp. 2222–2225
Publisher: IEEE Computer Society
Abstract: In this paper, we focus on the three-dimensional honeycomb point-lattice in which the Voronoi regions are hexagonal prisms. The ideal interpolation function is derived by using a Fourier transform of the sampling lattice. From these results, the sampling efficiency of the lattice follows.

13. **Estimation of Linear Deformations of 3D Objects**
Authors: Attila Tanacs(1), **Joakim Lindblad**, Nataša Sladoje(2), Zoltan Kato(1)
(1) Dept. of Image Processing and Computer Graphics, University of Szeged, Szeged, Hungary
(2) Faculty of Technical Sciences, University of Novi Sad, Serbia
Conference: 17th International Conference on Image Processing (ICIP), Hong Kong, China, September 26-29, pp. 153–156
Publisher: IEEE Computer Society
Abstract: We propose a registration method to find affine transformations between 3D objects by constructing and solving an overdetermined system of polynomial equations. We utilize voxel coverage information for more precise object boundary description. An iterative solution enables us to easily adjust the method to recover e.g. rigid-body and similarity transformations. Synthetic tests show the advantage of the voxel coverage representation, and reveal the robustness properties of our method against different types of segmentation errors. The method is tested on a real medical CT volume.

14. **On the Quality of Point Set Triangulations based on Convex Hulls**
Authors: Peter Jenke(1), **Anders Hast**, **Stefan Seipel**
(1) University of Gävle
Conference: SIGRAD, Swedish Chapter of Eurographics, Västerås, November 25-26, pp. 71–74
Editors: Kai-Mikael Jää-Aro and Thomas Larsson
Publisher: Linkping University Electronic Press, Linkping University
Abstract: In this paper we describe a method for directly generating triangle strips from unstructured point clouds based on onion peeling triangulation (OPT). It is an iterative reconstruction of the convex hulls of point clouds in the 2D plane, and it uses pairs of subsequent layers to establish triangle strips. We compare the obtained triangulations with the results of Delaunay triangulations in terms of the distribution of the symmetry of obtained triangles and in regard to the number of polygons/vertices emitted. Our initial results show that onion peeling is a straightforward method to directly obtain large triangle strips of point clouds. As expected, the triangulation is not as well behaved as in Delaunay-triangulation [VK07]. In terms of triangle complexity and average strip length OPT is a very favorable triangulation alternative which also lends suitable for the triangulation of 3D point clouds.

6.4 Non-refereed conferences and workshops

1. **Extending Distance Computation - Propagating Derivatives**
   Authors: **Anders Brun**
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic
   Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 39–42

2. **The Sum of Minimal Distances as a Useful Distance Measure for Image Registration**
   Authors: **Vladimir Curic**, **Joakim Lindblad**, Nataša Sladoje(1)
   (1) Faculty of Technical Sciences, University of Novi Sad, Serbia
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic
   Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 55–58

3. **Heuristics for Grey-weighted Distance Computations**
   Author: **Magnus Gedda**
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic
   Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12,, pp. 43–46

4. **Image-based Comparison of Pre-modern Coins and Medals**
   Authors: **Jens Hedrich**, Dietrich Paulus(1), Hendrik Mäkeler(1), **Ewert Bengtsson**
   (1) Institute for computer visualisation, University of Koblenz-Landau, Germany
   Conference: 16th Workshop Farbbildverarbeitung, Ilmenau, Germany, October 7-8, pp. 156–169

5. **Towards Identification of Highly Pathogenic Viruses Based on Image Analysis and TEM**
   Author: **Gustaf Kylberg**, Mats Uppström(1), Kjell-Olof Hedlund(2), **Ida-Maria Sintorn**
   (1) Vironova AB
   (2) Swedish Institute for Infectious Disease Control
   Conference: TAMSEC, National Symposium on Technology and Methodology for Security and Crisis Management, Linköping, October 27-28

6. **Path Openings and Their Applications**
   Author: **Cris L. Luengo Hendriks**
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic
   Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 79–82

7. **Image Foresting Transform: On-the-fly Computation of Region Boundaries**
   Authors: **Filip Malmberg**
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic
   Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 51–54

8. **Relaxed Image Foresting Transforms for Interactive Volume Image Segmentation**
   Authors: **Filip Malmberg**, **Ingela Nyström**, Andrew Mehnert(1), Craig Engstrom(1) , **Ewert Bengtsson**
   (1) University of Queensland (Australia)
   Conference: Proc. of SPIE-The International Society for Optical Engineering, San Diego, USA, February 13-18, 7623(762340), Electronic publication, 11 pages

9. **Image Registration using Particle swarm optimization approach**
   Author: **Muhammad Khalid Khan Niazi**, **Jens Hedrich**, **Ingela Nyström**
   Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
   Editors: C. Luengo and M. Gavrilovic

Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 31–34

10. **Methods for 3D Visualization of Bone Tissue in the Proximity of Implants**
Author: **Hamid Sarve**, **Joakim Lindblad**, Carina B Johansson(1)
(1) School of Health, Örebro University
Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
Editors: C. Luengo and M. Gavrilovic
Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 149–152

11. **Using a ring-shaped region around the optic disc in retinal image registration of Glaucoma patients**
Author: **Bettina Selig**, **Muhammad Khalid Khan Niazi**, **Ingela Nyström**
Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
Editors: C. Luengo and M. Gavrilovic
Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 35–38

12. **Sampling and Aliasing Properties of Three-Dimensional Point-Lattices**
Author: **Robin Strand**
Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
Editors: C. Luengo and M. Gavrilovic
Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 23–26

13. **Digital Distance Functions on a Honeycomb Point Lattice**
Authors: **Robin Strand**, Benedek Nagy(1)
(1) Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary
Conference: Workshop on Applications of Discrete Geometry and Mathematical Morphology, Istanbul, Turkey, August 22, pp. 17–21

14. **Towards Automatic Visualization of MET Biomedical Data**
Author: **Lennart Svensson**
Conference: Swedish Symposium on Image Analysis, Uppsala (SSBA)
Editors: C. Luengo and M. Gavrilovic
Publisher: Swedish Society for Automated Image Analysis, CBA report No. 34, Uppsala, March 10-12, pp. 83–86

15. **A Curvature Based Lightning Model for Quai-global Diffuse Illumination**
Authors: **Stefan Seipel**, Fei Liu and **Martin Ericsson**
Conference: Eurographics 2010, May 3-7, Linköping
Comment: Reviewed poster

6.5 Other publications

See also Section 3.2 for Master theses finished during 2010.

1. **Proceedings SSBA 2010: Symposium on Image Analysis**
Editors: **Cris L. Luengo Hendriks**, **Milan Gavrilovic**
Publisher: Centre for Image Analysis, 157 pages.

2. **CBA Annual Report 2009**
Editors: **Ewert Bengtsson**, **Vladimir Curic**, **Erik Wernersson**, **Ingela Nyström**, **Robin Strand**, **Lena Wadelius**
Publisher: Centre for Image Analysis, 95 pages.

7 Activities

Apart from the activities reported in previous Sections, we also spend much time and effort on outside contacts. These contacts are aimed at colleagues in academia, at industries based on image analysis or need of it, and at society in general. We participate in conferences; give and organize seminars; receive visitors and make visits, both for long and short stays; and participate in many different committees, both international and national. In the following Section, we have listed these activities for the year 2010. We have left out all meetings within ongoing research projects and all lectures we have given or attended as part of the regular educational activities. Still, the lists are quite extensive.

This year CBA personnel received one award: Maria Axelsson was awarded with Benzelius award from the Royal Society of Sciences in Uppsala.

Professor Stefan Seipel has served as Vice-chair of the Swedish Society for Computer Graphics (SIGRAD). Professor Ewert Bengtsson continued to serve as advisor to the Rector of UU on information technology and also as Chair of the UU IT-council, together with many other related appointments. Professor Gunilla Borgefors was Area Editor for Pattern Recognition Letters and is now appointed Editor in Chief.

To give some figures: We held as many as 19 seminars outside CBA, mostly in the Uppsala area, but also in The Netherlands, Serbia and South Korea. We had 16 invited seminars at CBA, from the UK, USA, France, South Korea, India, Australia and Sweden. In addition, we held 26 seminars in our "Monday seminar series", of which nine were Master Thesis presentations. We gave six special invited talks as well as three oral and eight poster presentations at international fully reviewed conferences, and 25 other oral conference presentations. We had long-term visitors from South Korea, Germany, Serbia, The Netherlands, USA, and India. In addition, Erik Wernersson payed a long visit to University of Jyväskylä, Finland, and Amin Allalou to Massachusetts Institute of Technology, Cambridge, USA. Joakim Linblad payed several longer visits to the Faculty of Engineering, University of Novi Sad, Serbia. We have also had a large number of national and international short-term visitors at many different occasions and have often visited others ourselves. Finally, we have listed 35 international and 45 national "committees" of the most varying types in which we have served.

7.1 Awards

1. **A Benzelius Award from the Royal Society of Sciences in Uppsala**
   Recipient: Maria Axelsson
   Date: 100831
   Description: Axelsson received the award for her PhD thesis: Image Analysis for Volumetric Characterisation of Microstructure, that she presented at CBA in 2009.

7.2 Organised conferences and workshops

1. **20th International Conference on Pattern Recognition, (ICPR 2010)**
   Organisers: Gunilla Borgefors
   Address: Istanbul, Turkey
   Date: 100101–100831
   Comment: Borgefors was Area Co-chair of Track II: Pattern Recognition and Machine Learning.

2. **Inje-Uppsala Workshop on Microscopy Image Analysis**
   Organisers: Ewert Bengtsson
   Address: Sälen ski resort and CBA seminar room
   Date: 100201–100206

Comment: Organized this one week long workshop with sessions 3-4 hours each day for a smaller a group and all day Friday for all of CBA and our Korean guests.

3. **Swedish Symposium on Image Analysis (SSBA 2010)**
   Organiser: CBA
   Address: Centre for image Analysis, Uppsala
   Date: 100310–100312
   Comment: CBA hosted the Swedish Symposium on Image Analysis this year. We had approximately 100 participants from academia and industry who gathered for a PhD student day and two symposium days.

4. **5th EGEE User Forum 2010**
   Organisers: Ingela Nyström, Lena Wadelius
   Address: Uppsala University Main Building
   Date: 100412–100415
   Comment: UPPMAX hosted the EGEE User Forum 2010 with approximately 300 participants from academia and industry. Mainly there were participants from Sweden and Europe, but also other continents. CBA staff involved in the 4-day event were Ingela Nyström, Lena Wadelius, and Martin Ericsson.

5. **Eurographics 2010**
   Organiser: Stefan Seipel
   Address: Linköping University, Campus Norrköping
   Date: 100503–100507
   Comment: Seipel was chairing the IPC/short papers conference together with Hendrik Lensch, Ulm.

6. **Workshop on Cell Image Analysis for Cervical Cancer Detection**
   Organiser: Ewert Bengtsson
   Address: CBA
   Date: 100924–100930
   Comment: Detailed discussions on progress in our joint project.

7.3 Seminars held outside CBA

1. **Anders Brun**
   Date: 100126
   Address: Centre for the Humanities, UU
   Title: OCR-tolkning av äldre källmaterial - Vad kan (och bör) man göra?

2. **Gunilla Borgefors**
   Date: 100324
   Address: Innventia AB, Stockholm
   Title: Image Analysis in 3D
   Comment: A seminar given at the inauguration of the Xradia machine at Innventia.

3. **Ida-Maria Sintorn**
   Date: 100325
   Address: Swedish Civil Contingencies Agency, Stockholm
   Title: Oral Project Report, PanViruShield
   Comment: Swedish Defense MAteriel ADministration, Swedish Civil Contingencies Agency and Swedish Governmental Agency for Innovation Systems representatives present.

4. **Ewert Bengtsson**
   Date: 100517
   Address: Delft University of Technology, Netherlands
   Title: Biomedical Image Analysis in Many Dimensions
   Comment: Bengtsson gave a one hour presentation about our work to the faculty and graduate students in Delft.

5. **Bettina Selig**
   Date: 100520
   Address: Siegbahnsalen, Ångström laboratory

Title: Segmentation of Compression Wood Cells
Comment: The seminar was given during the TekNat PhD student day.

6. **Gustaf Kylberg**
Date: 100520
Address: Siegbahnsalen, Ångström laboratory
Title: Towards Automatic Virus Diagnostics Using Digital Image Analysis
Comment: The seminar was given during the TekNat PhD student day.

7. **Ewert Bengtsson**
Date: 100525
Address: Uppsala Learning Lab, Blåsenhus Campus, Uppsala
Title: Virtual Faculties and Virtual Worlds - Organisation and Vision in the IT-field
Comment: Bengtsson gave a presentation about the development of IT support in learning at Uppsala University at the occasion of the 10th anniversary of Uppsala Learning Lab.

8. **Hamid Sarve**
Date: 100622
Address: Center for Mathematics and Statistics, Faculty of Technical Sciences, University of Novi Sad, Serbia
Title: Image Analysis for Evaluation of Bone-Implant Integration

9. **Vladimir Curic**
Date: 100622
Address: Center for Mathematics and Statistics, Faculty of Technical Sciences, University of Novi Sad, Serbia
Title: Set Distances and Their Applicability for Binary Image Registration

10. **Stina Svensson**
Date: 100727
Address: Science research school, Karlskoga
Title: Undersök världen med hjälp av digitala bilder
Comment: Lecture given at the science research school in Karlskoga for upper secondary school pupils from all over the country. It is organised every summer by PhD students from Swedish Universities.

11. **Hamid Sarve**
Date: 100818
Address: Inje University, South Korea
Title: 2nd Korea-Sweden Joint Workshop on Medical Image Analysis
Comment: Sarve gave the talk “3D Imaging and Visualization of Bone Tissue in the Proximity of Implants”

12. **Lennart Svensson**
Date: 100924
Address: Karolinska Institute, Stockholm
Title: ProViz - A Software Tool for Interactive Exploration of EM Volumes

13. **Ida-Maria Sintorn**
Date: 101111
Address: BioVis symposium, Dept. of Genetics and Pathology, UU
Title: What is Image Analysis and How Can It Help You? - Application Examples From Microscopy
Comment: Presentation of CBA and introduction and examples to image analysis as part of the BioVis symposium “Image Analysis: beyond pretty pictures”

14. **Cris Luengo**
Date: 101111
Address: BioVis symposium, Dept. of Genetics and Pathology, UU
Title: BioVis Symposium

15. **Milan Gavrilovic**
Date: 101111
Address: BioVis symposium, Dept. of Genetics and Pathology, UU

Title: Quantification of Multi-colored Signals in situ - or How Image Analysis Can Help Developing Biochemical Methods

16. **Ida-Maria Sintorn**
*Date:*101115
Address: Umeå Plant Science Centre
Title: What is Image Analysis and How Can It Help You? - Application Examples From Microscopy
Comment: Sintorn visited Umeå Plant Science Centre and Karin Ljung at the Dept. of Forest Genetics and Plant Physiology to discuss possible collaboration.

17. **Anders Brun**
Date: 101116
Address: School of Computer Science and Communications, Royal Institute of Technology, Stockholm
Title: Inside Data, Inside Algorithms

18. **Ingela Nyström**
Date: 101117
Address: PDC Center for High Performance Computing, Royal Institute of Technology, Stockholm
Title: Visualization and Haptics for Interactive Medical Image Analysis - Image Segmentation in Craniomaxillofacial Surgery Planning
Comment: Invitation to a seminar series on e-Science.

19. **Gustaf Kylberg**
Date: 101126
Address: Swedish Defence Materiel Administration, Stockholm
Title: Oral project report, PanViruShield
Comment: Swedish Civil Contingencies Agency, Swedish Defense Materiel Administratoin and Swedish Governmental Agency for Innovation Systems representatives present.

7.4 Special invited speakers

1. *Conference:* Summer School on Image Processing 2010 (SSIP'10)
Joakim Lindblad
Date: 100708–100717
Address: Faculty of Electronics, Telecommunications and Information Technology, Technical University of Cluj-Napoca, Romania
Title: Pixel coverage models, segmentation, and feature extraction
Comment: SSIP is organized annually for graduate and PhD students interested in image processing

2. *Conference:* International Federation of Library Associations and Institutions Satellite meeting: New Technologies for Old Documents
Gunilla Borgefors
Date: 100816–100818
Address: Uppsala
Title: Computerized Character Recognition – Prerequisites and Possibilities

3. *Conference:* BioIT Europe
Ewert Bengtsson
Date: 101005–101006
Address: Hannover Conference Grounds, Germany
Title: Quantiative Image Analysis Tools for Biological Research

4. *Conference:* Bio-IT World Conference 2010
Ingela Nyström
Date: 101011–101013
Address: Exhibition Grounds, Hannover, Germany
Title: The First Success Stories after the Swedish Buildup of Computational Power and Large-Scale Storage for Gene-Sequence Data
Comment: Nyström represented UPPMAX and Uppsala University as invited speaker, session chair, and moderator of round table discussion.

5. *Conference:* Modeling with Images in the Life Sciences
   Cris Luengo
   Date: 101129–101203
   Address: Lorentz Center, Leiden University, The Netherlands
   Title: Image Processing and Visualization in Developmental Biology.
   Comment: Luengo moderated a discussion session.

6. *Conference:* 2010 IEEE International Conference on Computational Intelligence and Computing Research
   Ewert Bengtsson
   Date: 101228–101229
   Address: Tamilnadu College of Engineering,Coimbatore, India
   Title: Recognizing Signs of Malignancy - the Quest for Computer Assisted Cancer Screening and Diagnosis Systems
   Comment: Bengtsson was invited as the international keynote speaker of this international conference with about 250 participants.

7.5 Seminars at CBA with invited guest lecturers

1. **Apostolos Antonacopoulos**
   Address: University of Salford, Pattern Recognition and Image Analysis (PRImA) Lab, UK
   Date: 100311
   Title: Large-Scale Digitisation and Recognition of Historical Documents: Challenges and Opportunities for Image Processing and Analysis

2. **S. H. Lau**
   Address: Xradia Inc.
   Date: 100324
   Title: Novel Lab Based X-ray Tomography System for Multiscale 3D Characterization

3. **Bo Blomgren**
   Address: AstraZeneca R&D Södertälje
   Date: 100406
   Title: Stereology-based Image Analysis in Biology

4. **Punam K. Saha**
   Address: Dept. of Electrical and Computer Engineering, Dept. of Radiology, University of Iowa, USA
   Date: 100521
   Title: Multi-scale Topo-morphologic Approaches and Their Applications to Medical Imaging

5. **Rémy Malgouyres**
   Address: University of Clermont, France
   Date: 100527
   Title: Cached Multi-bounce Solution and Reconstruction for Voxel-based Global Illumination

6. **Carl Sjöberg**
   Address: Dept. of Oncology, Radiology and Clinical Immunology, UU
   Date: 100607
   Title: Atlas-based Segmentation of the Prostate for the Planning of Radiotherapy

7. **Pasha Razifar**
   Address: GE Health Care, Uppsala
   Date: 100915
   Title: Ugly Yet Informative vs. Fine-looking but Frozen Information–Which one Should be the Future of PET Imaging
   Comment: Docent lecture.

8. **Rajesh Kumar**
   Address: Centre for Development of Advanced Computing, Thiruvananthapuram, India
   Date: 100927
   Title: Medical Image Analyser for Cervical Cancer

9. **Kenneth Wikström**
   Address: Dept. of Oncology, Radiology and Clinical Immunology, UU
   Date: 101004
   Title: Patient Positioning in Radiotherapy Using Body Surface Laser Scanner

10. **Gert Kootstra**
    Address: Royal Institute of Technology, Stockholm
    Date: 101011
    Title: Bottom-Up Object Detection and Segmentation Using Gestalt Principles

11. **Carl Henrik**
    Address: Royal Institute of Technology, Stockholm
    Date: 101011
    Title: Graphical Models in Grasping

12. **Stefan Robila**
    Address: Center for Imaging and Optics, Dept. of Computer Science, Montclair State University, USA
    Date: 101025
    Title: Efficient Use of Hyperspectral Imagery

13. **Henrik Johansson**
    Address: Digital Production Division, National Library of Sweden
    Date: 101101
    Title: Colorite: a Flexible Cross-platform Software Solution for Automatic Image Quality Analysis Using Arbitrary Targets

14. **Gustaf Ullman**
    Address: Computational and Systems Biology, Dept. of Cell and Molecular Biology, UU
    Date: 101122
    Title: Extracting Quantitative Data from Thousands of Cells - Towards Automatic Segmentation, Tracking and Spot Detection

15. **Andrew P. Bradley**
    Address: The University of Queensland, School of Information Technology and Electrical Engineering, Australia
    Date: 101129
    Title: Group Based Classification for Medical Diagnostics

16. **Anthony Maeder**
    Address: School of Computing and Mathematics, University of Western Sydney, Australia
    Date: 101217
    Title: The UWS

7.6 Seminars at CBA

Seminars by seniors, PhD students and Master thesis students at CBA.
Some of these seminars were held in Swedish.

1. **Robin Strand**
   Date: 100111
   Title: Interpolation Functions for Three-dimensional Grids

2. **Anders Brun**
   Date: 100118
   Title: Propagating Distances, Directions and Derivatives

3. **Filip Malmberg**
   Date: 100125
   Title: Segmentation of Muscles from Magnetic Resonance Images

4. **Ida-Maria Sintorn**
   Date: 100201
   Title: PanViruShield - Project Update
5. **Lennart Svensson**
   Date: 100208
   Title: Investigating Automatic Transfer Functions for Volume Rendering of Molecular Electron Tomography Data
6. **Anders Hast**
   Date: 100209
   Title: Phongs Belysningsmodell – hur den förbättrats genom åren
   Comment: Docent degree presentation.
7. **Amin Allalou and Hamid Sarve**
   Date: 100215
   Title: Presentation of Izolde Image Intelligence
8. **Fredrik Olsson**
   Date: 100222
   Title: Visualization of Military Camp Sites
   Comment: Master thesis presentation.
9. **Kelly Hubble**
   Date: 10025
   Title: Digital Straight Line Segment Recognition on Non-Standard Point Lattices
   Comment: Master thesis presentation.
10. **Gustaf Kylberg**
    Date: 100301
    Title: Classifiers for Classifying Virus Data
11. **Ingrid Carlbom**
    Date: 100308
    Title: Whole Hand Haptics with True 3D Displays
12. **Cris Luengo**
    Date: 100315
    Title: Owl and the CBA library
13. **Bettina Selig**
    Date: 100322
    Title: Segmentation of Compression Wood Cells
14. **Patrik Malm**
    Date: 100329
    Title: Simulated Bright-Field Images of Cervical Smears
15. **Vladimir Curic**
    Date: 100412
    Title: Binary Image Registration Based on Set Distances
16. **Ewert Bengtsson**
    Date: 100426
    Title: Eurobioimaging and the Swedish Bioimaging Network
17. **Ying Wang**
    Date: 100419
    Title: Analysis Application for H.264 Video Encoding
    Comment: Master thesis presentation
18. **Khalid Niazi**
    Date: 100503
    Title: A Brief Tutorial on Scale-Invariant Feature Transform

19. **Erik Wernersson**
    Date: 100510
    Title: Quantifying Large Defects and Measuring Fibre Wall Thickness in CT Images of Wood Fibre Composites

20. **Magnus Gedda**
    Date: 100517
    Title: Rehearsal before the public defense of the thesis

21. **Jens Hedrich**
    Date: 100524
    Title: Image Analysis to Identify Pre-modern Coins and Medals
    Comment: Master thesis presentation.

22. **Erik Almlöf**
    Date: 100528
    Title: What is Most Important in a City? Development of a Localization Tool for Urban Planning
    Comment: Master thesis presentation.

23. **Kristin Norell**
    Date: 100531
    Title: Rehearsal before the public defense of the thesis

24. **Johan Nysjö**
    Date: 100614
    Title: Orbit Segmentation for Cranio-maxillo-facial Surgery Planning
    Comment: Master thesis presentation.

25. **Milan Gavrilovic**
    Date: 100816
    Title: Automated Classification of Multi-coloured Point-like Signals in Fluorescence Microscopy

26. **Azadeh Fakhrzadeh**
    Date: 100823
    Title: Minimum Noiseless Description Length (MNDL) Thresholding

27. **Javier Fernandez**
    Date: 100824
    Title: Image Processing to Detect Worms
    Comment: Master thesis presentation.

28. **Daniel Skog**
    Date: 100830
    Title: Gait-based Reidentification of People in Urban Surveillance Video
    Comment: Master thesis presentation.

29. **Jimmy Azar**
    Date: 100913
    Title: Automated Tracking of the Carotid Artery in Ultrasound Image Sequences Using an Incremental Self-Organizing Neural Network

30. **Elisabeth Linnér**
    Date: 100920
    Title: Sparse Approximate Inverses in a Finite Element Framework

31. **Pontus Olsson**
    Date: 101018
    Title: Cooperative Control of Virtual Objects using Haptic Teleoperation over the Internet

32. **Carolina Wählby**
    Date: 101028
    Title: Drug Discovery by Image-based High-throughput Screening Using C Elegans

33. **Åsa Nyflött**
Date: 101108
Title: Development of an Image Processing Tool for Fluorescence Microscopy Analysis of Paper Chemistry
Comment: Master thesis presentation.

34. **Anders Hast**
Date: 101115
Title: High Performance Computing at CINECA - A Multiscale Texture Synthesis Implementation

35. **Filip Malmberg**
Date: 101206
Title: A Report from the Sao Paulo Advanced School of Computing

36. **Catherine Östlund**
Date: 101214
Title: Characterization of Paper (Micro)structure
Comment: Several researchers associated with Ångströms Materialakademi visited CBA to hear about our research related to material sciences.

37. **Bettina Selig**
Date: 101214
Title: Digital Image Analysis on Wood Fibers
Comment: Several researchers associated with Ångströms Materialakademi visited CBA to hear about our research related to material sciences.

38. **Hamid Sarve**
Date: 101214
Title: Characterization of Bone-implant Interface
Comment: Several researchers associated with Ångströms Materialakademi visited CBA to hear about our research related to material sciences.

7.7 Conference participation

7.7.1 Oral presentations – refereed conferences

1. *Conference:* International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing 2010
Stefan Seipel
Date: 100503–100507
Address: Rome, Italy
Title: A Local Curvature Based Lighting Model for Rendering of Snow

2. *Conference:* International Conference on Computer Vision and Graphics (ICCVG 2010)
Hamid Sarve
*Date:*100920–100923
Address: Warsaw, Poland
Title: Methods for Visualization of Bone Tissue in the Proximity of Implants

3. *Conference:* SIGRAD 2010
Anders Hast, Stefan Seipel
Date: 101125–101126
Address: Mälardalen University, Västerås
Title: On the Quality of Point Set Triangulations based on Convex Hulls

7.7.2 Poster presentations – refereed conferences

1. *Conference:* SPIE Medical Imaging
Filip Malmberg
Date: 100213–100218

Address: San Diego, USA
Title: Relaxed Image Foresting Transforms for Interactive Volume Image Segmentation

2. *Conference:* International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2010)
Magnus Gedda
Date: 100315–100319
Address: Dallas, Texas, USA
Title: Three-dimensional Tracing of Neurites in Fluorescence Microscopy Images Using Local Path-finding

3. *Conference:* IEEE International Symposium on Biomedical Imaging (ISBI 2010)
Patrik Malm
Date: 100414–100417
Address: Rotterdam, Netherlands
Title: PAPSYNTH: Simulated Bright-Field Images of Cervical Smears

4. *Conference:* Eurographics 2010
Stefan Seipel
Date: 100503–100507
Address: Linköping University, Campus Norrköping
Title: A Curvature Based Lightning Model for Quasi-global Diffuse Illumination

5. *Conference:* Workshop on Applications of Discrete Geometry and Mathematical Morphology
Robin Strand
Date: 100822
Address: Istanbul, Turkey
Title: Digital Distance Functions on a Honeycomb Point Lattice

6. *Conference:* International Conference on Pattern Recognition (ICPR 2010)
Robin Strand
Date: 100823–100827
Address: Istanbul, Turkey
Title 1: Interpolation and Sampling on a Honeycomb Lattice
Title 2: Sampling and Ideal Reconstruction on the 3D Diamond Grid

7. *Conference:* International Conference on Pattern Recognition (ICPR 2010)
Joakim Lindblad
Date: 100823–100827
Address: Istanbul, Turkey
Title: De-noising of SRμCT Fiber Images by Total Variation Minimization

8. *Conference:* International Conference on Pattern Recognition (ICPR 2010)
Khalid Niazi
Date: 100823–100827
Address: Istanbul, Turkey
Title: A Modified Particle Swarm Optimization Applied in Image Registration

7.7.3 Oral presentations - non-refereed conferences

1. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Ewert Bengtsson
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Welcoming and opening remarks
Comment: Organized this one week long workshop with sessions 3-4 hours each day for a smaller a group and all day Friday for all of CBA and our Korean guests.

2. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Gustaf Kylberg
Date: 100201–100206

Address: Sälen ski resort and CBA seminar room
Title: Identification of Highly Pathogenic Viruses in Transmission Electron Microscopy Images

3. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Amin Allalou
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Detection of Biomolecules in Cells

4. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Erik Wernersson
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Analysis of Fibrous Composite Materials using Micro-Computed Tomography

5. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Hamid Sarve
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: GPU-aided 3D Visualization of Bone Tissue in the Proximity of Implants

6. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Cris Luengo
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: The Three-dimensional Fruit-fly Embryo

7. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Patrik Malm
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Curve Closing by Gradient Weighted Distance Transformation Applied in Automated Cervical Cancer Screening

8. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Muhammad Khalid Khan Niazi
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Analysis of Heart Beats of Rat Embryos

9. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Bettina Selig
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Measuring Highly Lignified Areas in Wood Fiber Cross-sections

10. *Conference:* Inje-Uppsala Workshop on Microscopy Image Analysis
Milan Gavrilovic
Date: 100201–100206
Address: Sälen ski resort and CBA seminar room
Title: Spectral Image Analysis in Fluorescence Microscopy: Quantification of Colocalization by Spectral Angles

11. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Hamid Sarve
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Methods for 3D Visualization of Bone Tissue in the Proximity of Implants

12. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Lennart Svensson
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Towards Automatic Visualization of MET Biomedical Data

13. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Bettina Selig
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Using a Small Stable Region in Retinal Image Registration

14. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Cris Luengo
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Path Openings and Their Applications

15. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Filip Malmberg
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Image Foresting Transform: On-the-fly Computation of Region Boundaries.

16. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Khalid Niazi
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Image Registration Using Particle Swarm Optimization Approach

17. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Magnus Gedda
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Heuristics for Grey-weighted Distance Computations

18. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Anders Brun
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Extending Distance Computation–propagating Derivatives

19. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Robin Strand
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: Sampling and Aliasing Properties of Three-Dimensional Point-Lattices

20. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Vladimir Curic
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala
Title: The Sum of Minimal Distances as a Useful Distance Measure for Image Registration

21. *Conference:* The 6th Uppsala Spring Meeting - The Future of Molecular Imaging /New technology and scientific challenges to meet clinical needs
Robin Strand
Date: 100412–100414
Address: Uppsala Concert and Congress Centre
Title: Image Processing and Analysis

22. *Conference:* Visual Forum'10
Ingrid Carlbom
Date: 100503
Address: Norrköping, Sweden
Title: Whole Hand Haptics with True 3D Displays

23. *Conference:* ISO working group on "Tactile and haptic interaction"
Ewert Bengtsson
Date: 100507
Address: Pedagogikum, Blåsenhus Campus, Uppsala
Title: Research on Haptics at Uppsala University
Comment: Bengtsson was invited to present our research project to this international working committee.

24. *Conference:* Sao Paolo Advanced School of Computing
Filip Malmberg
Date: 100712–100717
Address: Sao Paolo, Brazil
Title: Graph-Based Image Segmentation with Sub-Pixel Precision
Comment: Malmberg presented his work at the summer school.

25. *Conference:* Korea-Sweden Joint Workshop on Medical Image Analysis
Ewert Bengtsson, Patrik Malm, Andreas Kårsnäs, Hamid Sarve
Date: 100817–100820
Address: Jeju Island, South Korea
Title: CBA Image Analysis
Comment: A joint one week workshop with presentation of participants from both groups.

7.7.4 Poster presentations - non-refereed conferences

1. *Conference:* Eurographics 2010
Stefan Seipel, Fei Liu, Martin Ericsson
Date: 100503–100507
Address: Linköping University, Campus Norrköping
Title: A Curvature Based Lightning Model for Quasi-global Diffuse Illumination

2. *Conference:* TAMSEC
Gustaf Kylberg
Date: 101027–101028
Address: Collegium, Linköping
Title: Towards Identification of Highly Pathogenic Viruses Based on Image Analysis and TEM
Comment: TAMSEC is a National Symposium on Technology and Methodology for Security and Crisis Management. Printed proceedings with one page abstract.

3. *Conference:* IMAGIC seminar 2010
Catherine Östlund
Date: 101123–101124
Address: Electrum, Kista
Title: Revealing Paper Structure in 3D Using X-ray Tomography

7.7.5 Attended conferences

1. *Conference:* Swedish Symposium on Image Analysis (SSBA 2010)
Ewert Bengtsson, Ida-Maria Sintorn, Ingrid Carlbom, Milan Gavrilovic, Gunilla Borgefors, Catherine Östlund, Erik Wernersson, Amin Allalou, Patrik Malm, Joakim Lindblad
Date: 100310–100312
Address: Ångströmslaboratoriet, Uppsala

2. *Conference:* Visual Forum 2010
Ewert Bengtsson, Catherine Östlund
Date: 100503
Address: Louis De Geer conference centre, Norrköping
Comment: National conference on visualisation.

3. *Conference:* SIGGRAPH 2010
Ingrid Carlbom
Date: 100726–100729
Address: Los Angeles, CA, USA

4. *Conference:* 20th International Conference on Pattern Recognition (ICPR 2010)
Ewert Bengtsson, Ingela Nyström
Date: 100822–100826
Address: Istanbul Convention & Exhibition Centre, Istanbul, Turkey
Comment: Nyström was Swedish representative at the IAPR Governing Board meeting. She was elected Secretary of the IAPR. The Swedish bid to host ICPR 2014 in Stockholm was elected.

5. *Conference:* Image Analysis: beyond pretty pictures
Ewert Bengtsson, Milan Gavrilovic, Cris Luengo, Ida-Maria Sintorm
Date: 101111
Address: Rudbeck laboratory, Uppsala

7.7.6 Other conferences

In this Section, we list attended non-image processing conferences.

1. *Conference:* TDB 2010
Ewert Bengtsson, Ingela Nyström, Erik Wernersson
Date: 100111–100112
Address: Gimo Herrgård Conference Centre
Comment: Internal conference arranged by the Div. of Scientific Computing (TDB) at the Dept. of Information Technology.

2. *Conference:* Typology of Numerical Systems
Gunilla Borgefors
Date: 100123
Address: Botanical Garden, UU
Comment: Seminar by Bernard Comrie, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany, organised by Swedish Collegium for Advanced Studies organised by Swedish Collegium for Advanced Studies.

3. *Conference:* UUplus course
Ewert Bengtsson, Lena Wadelius
Date: 100212
Address: Economicum, Uppsala
Comment: Attended a half day course to learn how to use this new overly complicated budgeting tool.

4. *Conference:* World Class IT Uppsala (In Swedish:Världsklass IT Uppsala)
Ewert Bengtsson
Date: 100302
Address: Uppsala Consert and Conference Centre
Comment: One of the representatives of Uppsala University to this conference about IT based business and research in Uppsala.

5. *Conference:* SLU prefektmöte (Meeting for department heads at SLU)
Ewert Bengtsson
Date: 100325
Address: Eklundshof Conference Centre, Uppsala

6. *Conference:* How to write a good VR application
   Ewert Bengtsson
   Date: 100329
   Address: BMC, Uppsala
   Title: Advice on how to write a good application to the Swedish Science Council
   Comment: Young researchers at UU planning to submit proposals to VR were invited to this workshop.

7. *Conference:* Workshop on the Future web of UU
   Ewert Bengtsson
   Date: 100330
   Address: Uppsala Akademihotell
   Comment: Part of the process of developing a completely new website for UU.

8. *Conference:* Deans Meeting UU
   Ewert Bengtsson
   Date: 100412–100413
   Address: Villa Aske Conference Centre, Upplands Bro, Sweden
   Comment: Semiannual meeting of all deans and senior advisors to the vice chancellor of UU.

9. *Conference:* SLU Faculty days 2010
   Cris Luengo, Anders Brun, Ewert Bengtsson
   Date: 100427–100428
   Address: SLU, Umeå

10. *Conference:* National IT council In Swedish: Nationellt Branschråd inom IT
    Ewert Bengtsson
    Date: 100507
    Address: UKK, Uppsala Concert and Congress Centre
    Comment: Invited to attend this closed committee meeting about trends on the IT labour market.

11. *Conference:* PDC 20-year Anniversary and SNIC Interaction 2010
    Ingela Nyström
    Date: 100830–100831
    Address: Tammsvik Konferens Herrgård, Bro
    Comment: Nyström represented UPPMAX.

12. *Conference:* Scholars in Action: Past, present, future
    Ewert Bengtsson, Gunilla Borgefors
    Date: 101112
    Address: Lecture Hall X, Uppsala University main building
    Comment: Tercentenary Anniversary Symposium of the Royal Society of Sciences in Uppsala, 1710-2010.

13. *Conference:* Deans meeting UU
    Ewert Bengtsson
    Date: 101115–101116
    Address: Villa Aske Conference Centre, Upplands Bro, Sweden

14. *Conference:* Labex jury
    Ewert Bengtsson
    Date: 101207–101208
    Address: Campus des Cordeliers, 21 rue de l'Ecole de Médecine, 75006 Paris, France
    Comment: Initial meeting of an assignment to evaluate a set of French research proposals.

7.8 Visiting scientists (staying at least 2 weeks)

1. **Hyun-Ju Choi**
   Address: Inje University, South Korea
   Host: Ewert Bengtsson
   Date: 100101–100530

Topic: Texture analysis of cells and tissue
Comment: Hyun-Ju was staying here as visiting researcher also in 2009.

2. **Jens Hedrich**
Address: University of Koblenz-Landau, Germany
Host: Ewert Bengtsson
Date: 100101–100608
Topic: Image-Based Comparison of Pre-modern Coins and Medals
Comment: Heidrich was staying here as visiting researcher also in 2009.

3. **Nataša Sladoje**
Address: Faculty of Engineering, University of Novi Sad, Serbia
Host: Joakim Lindblad
Date: 100301–100321
Comment: Research cooperation, teaching at course "Fuzzy Sets and Fuzzy Techniques".

4. **Robiël Naziroglu**
Address: Quantitative Imaging Group, Delft University of Technology, The Netherlands.
Hosts: Cris Luengo, Catherine Östlund
Date: 100823–101222
Topic: Density and volume fraction estimation from micro-CT images
Comment: Naziroglu is a MSc student in Delft, he came here as an intern.

5. **Stefan Robila**
Address: Center for Imaging and Optics, Dept. of Computer Science, Montclair State University, Upper Montclair, NJ, USA
Host: Ewert Bengtsson
Date: 100906–101217
Topic: Multispectral image analysis
Comment: Robila was staying with us a bit more than three months discussing ideas about various image analysis projects and in particular on coin image analysis using spectral information.

6. **Kumar Sujathan**
Address: Pathology Department, Regional Cancer Centre, Thiruvananthapuram, India
Host: Ewert Bengtsson, Patrik Malm
Date: 100915–100928
Topic: 3D image acquisition for cytology research
Comment: Part of our Cerviscan collaboration project.

7.9 Other visitors

1. **Erik Temnerud**
Address: www.skogsdoktorn.se
Hosts: Gunilla Borgefors, Kristin Norell
Date: 100112
Topic: A meeting about a possible cooperation on measuring wood quality

2. **Heung-Kook Choi, Hae-Gil Hwang, Kyoung-Jong Park**
Address: Inje University, South Korea
Host: Ewert Bengtsson
Date: 100201–100206
Topic: Microscopy Image Analysis
Comment: Our visitors in addition to visiting CBA participated in a joint workshop.

3. **Jan Grawé**
Address: BioVis, Rudbecks lab, Uppsala university
Host: Ewert Bengtsson
Date: 100210
Topic: Increased collaboration between CBA and the BioVis lab

4. **Elisabeth Larsson**
   Address: Centre for Interdisciplinary Mathematics, UU
   Host: Gunilla Borgefors
   Date: 100212
   Topic: CBA involvement in Centre for Interdisciplinary Mathematics

5. **Hans Frimmel, Örjan Smedby**
   Address: IT-department, UU and CMIV, Linköping University
   Host: Ewert Bengtsson
   Date: 100212
   Topic: Discussed joint VR application

6. **SSBA Board meeting**
   Hosts: Ingela Nyström, Ida-Maria Sintorn
   Date: 100218
   Topic: SSBA Board Meeting

7. **Kristofer Gamstedt, Thomas Joffre**
   Address: Royal Institute of Technology, Stockholm
   Hosts: Cris Luengo, Anders Brun, Erik Wernersson
   Date: 100219
   Topic: WoodFibre 3D collaboration

8. **Jan Hirsch, Roman Khonsari**
   Address: UU Hospital
   Hosts: Ewert Bengtsson, Ingela Nyström
   Date: 100222
   Topic: About collaboration on 3D medical image analysis

9. **Tomas Lundmark, Annika Nordin**
   Address: SLU Faculty of Forestry
   Hosts: Ewert Bengtsson, Gunilla Borgefors
   Date: 100222
   Topic: About CBA as part of SLU Faculty of Forestry
   Comment: The new dean and pro dean visited to introduce themselves and get an understanding of CBA as part of the faculty.

10. **Thomas Börjesson, C. G. Pettersson, Jaan Luup**
    Address: Lantmännen Lantbruk, Lidköping; Lantmännen Lantbruk, Enköping; Maxx Automation, Uppsala
    Hosts: Ewert Bengtsson, Cris Luengo
    Date: 100303
    Topic: Possible collaboration
    Comment: This led to the start of a Master thesis project, Fraz Ali was hired to work at Maxx Automation, Cris is the ämnesgränskare.

11. **Jan Wikander, Magnus Eriksson**
    Address: Mechatronics group, Royal Institute of Technology, Stockholm
    Hosts: Ewert Bengtsson, Ingrid Carlbom
    Date: 100317
    Topic: Possible collaboration on stereology and image analysis
    Comment: Discussed haptics and robotics work in our two research groups.

12. **Bo Blomgren**
    Address: Astra Zeneca R&D Södertälje
    Host: Ewert Bengtsson
    Date: 100318
    Topic: Possible collaboration on stereology and image analysis

13. **Ingalill Karlsson**
    Address: Medical informatics and engineering, UU Hospital

Host: Ewert Bengtsson
Date: 100331
Topic: Possible collaboration between CBA and the hospital IT and medical engineering group

14. **Johan Elf**
Address: Uppsala Biomedical Center (BMC), UU
Hosts: Amin Allalou, Ewert Bengtsson, Ingela Nyström
Date: 100420
Topic: Discussion of possible joint project on analysis of time-lapse microscopy data and single molecule tracking.

15. **Demetri Terzopoulos**
Address: Computer Science Department, University of California, Los Angeles, USA
Hosts: Ingrid Carlbom, Ewert Bengtsson, Ingela Nyström
Date: 100510
Topic: Presentation of various projects on 3D modelling and visualization
Comment: Study visit of CBA in connection with the FMB Career Day.

16. **Demetri Terzopoulos**
Address: Computer Science Department, University of California, Los Angeles, USA
Host: Ingrid Carlbom
Date: 100511
Topic: Biomedical and Artificial Life Simulation of Humans
Comment: Visitor presented a seminar to CBA, FMB, and Centre for Interdiciplinary Mathematics (CIM).

17. **Sven Nilsson, Milan Golubovic**
Address: Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
Hosts: Filip Malmberg, Ingela Nyström
Date: 100528
Topic: Planning of our joint liver project

18. **Kristofer Gamstedt, Thomas Joffre, Andreas Köhler**
Address: Royal Institute of Technology, Stockholm
Hosts: Cris Luengo, Anders Brun, Erik Wernersson
Date: 100603
Topic: WoodFibre 3D collaboration

19. **Joel Kullberg**
Address: ORKI (Radiology) Department, UU Hospital
Hosts: Ewert Bengtsson, Robin Strand
Date: 100615
Topic: Collaboration on radiology image analysis

20. **Klaus Leifer**
Address: Institute of Electron Microscopy and Nano Engineering, UU
Hosts: Ewert Bengtsson, Ingrid Carlbom
Date: 100617
Topic: Possible collaboration on an EU application about detection of nano-particles

21. **Linnea Rundgren**
Address: Hägersten
Host: Ewert Bengtsson
Date: 100618
Topic: Presentation of Linneas scientific photography and discussions of possible collaborations

22. **Metin Gurcan**
Address: Dept. of Biomedical Informatics, College of Medicine, The Ohio State University, US
Host: Milan Gavrilovic
Date: 100623
Topic: Discussions about possible cooperation

23. **Felix de Haas**
Address: FEI Europe B.V., Achtseweg Noord 5, Eindhoven, The Netherlands
Host: Gustaf Kylberg
Date: 100907
Topic: Automatic acquisition using TEM

24. **Ravindra Kumar and Rajesh Kumar**
Address: CDAC, Thiruvananthapuram, India
Hosts: Ewert Bengtsson, Patrik Malm
Date: 100923–100930
Topic: 3D image acquisition for cytology research
Comment: Part of our Cerviscan collaboration project.

25. **Anna Byström**
Address: Dept. of Anatomy, Physiology and Biochemistry
Host: Anders Brun
Date: 101001
Topic: Collaboration, saddle pressure

26. **Gert Koostra, Carl-Henrik Ek**
Address: School of Computer Science and Communications, Royal Institute of Technology, Stockholm
Host: Anders Brun
Date: 101011
Topic: Computer Vision
Comment: Discussed collaboration with Royal Institute of Technology. Mainly courses, master theses and research.

27. **Magnus Borga, Anders Heyden, Karin Hornay**
Address: Dept. of Biomedical Engineering, Linköping University, Centre for Mathematical Sciences, Lund University, SLU, Uppsala
Hosts: Ewert Bengtsson, Gunilla Borgefors, Ingela Nyström
Date: 101020
Topic: Planning of ICPR 2014

28. **Jochen Wold**
Address: Dept. of Evolutionary Biology, Evolutionary Biology Centre, UU
Host: Anders Brun
Date: 101022
Topic: Research on bird plumage patterns
Comment: The project discussion resulted in a master thesis proposal.

29. **Ken Åberg**
Address: NewFormat AB, Hässelby
Host: Ewert Bengtsson
Date: 101119
Topic: Open Format software aspects

30. **Andrew Bradley**
Address: University of Queensland, Brisbane, Australia
Host: Ewert Bengtsson
Date: 101129
Topic: Collaborations on image analysis
Comment: Bradley spent a week in Uppsala with his family, visited CBA for seminar and informal discussions about continued cooperation.

31. **Bjorn S Tanem, Arttu Miettinen, Kristofer Gamstedt, Thomas Joffre**
Address: SINTEF, Trondheim, Norway, University of Jyväskylä, Finland, Royal Institute of Technology, Stockholm
Hosts: Cris Luengo, Anders Brun, Erik Wernersson, Gunilla Borgefors
Date: 101209

Topic: WoodFibre 3D project
Comment: Final project meeting.

32. **Anthony Maeder**
Address: Anthony Maeder, School of Computing and Mathematics, UWS, Australia
Host: Ewert Bengtsson
Date: 101217
Topic: Medical informatics and image analysis
Comment: Discussions of current work at each lab and seminar by the visitor.

7.10 Visits to other research groups (for at least 2 weeks)

1. **Joakim Lindblad**
Host: Nataša Sladoje, Silvia Ghilezan
Address: Faculty of Engineering, University of Novi Sad, Serbia
Topic: Joint research project
Comment: Several longer visits were made during the year.

2. **Erik Wernersson**
Host: Markku Kataja
Address: Dept. of Physics, University of Jyväskylä, Finland
Date: 100412–100430
Topic: Research Visit

3. **Amin Allalou**
Host: Mehmet Fatih Yanik
Address: Massachusetts Institute of Technology, Cambridge, MA, USA
Date: 100910–101013
Topic: High-throughput Zebra fish screening

7.11 Short visits to other research groups and meetings outside CBA

Note: Meetings occasioned by permanent appointments are listed in section 7.12

1. **Ida-Maria Sintorn**
Hosts: Jan-Olov Strömberg, Joel Andersson
Address: Dept. of Mathematics, Royal Institute of Technology, Stockholm
Date: 100113
Topic: Diffusion geometry for virus identification in TEM images
Comment: Discussing possible collaboration.

2. **Gunilla Borgefors, Gustaf Kylberg**
Host: Vironova
Address: Vironova AB, Stockholm
Date: 100205
Topic: Cooperation on virus analysis in SEM images

3. **Khalid Niazi**
Host: Mats Nilsson
Address: Dept. of Pharmaceutical Biosciences, Division of Toxicology, UU
Date: 100303
Topic: Discussion about Video Recording issues

4. **Lennart Svensson**
Hosts: Lars Norlén, Aurelie Laloeuf
Address: Karolinska Institute, Stockholm
Date: 100319
Topic: Collaboration discussions

5. **Gunilla Borgefors, Anders Brun**
   Address: StoraEnso Research Centre, Karlstad
   Date: 100319
   Topic: Start of joint Master Thesis on movement of particles in pulp
   Comment: Borgefors presented activities at CBA during the meeting. The Master student is Åsa Nyflött at Karlstad University.

6. **Milan Gavrilovic, Cris Luengo**
   Hosts: Jan Grawé, Dirk Pacholsky
   Address: Rudbeck Laboratory, UU
   Date: 100505
   Topic: Visit to The Cell Analysis Core Facility (BioVis)
   Comment: Discussing possible collaboration with the hosts and some specific applications at the UU Hospital. Planning of the 1st BioVis symposium on Image Analysis: beyond pretty pictures.

7. **Cris Luengo, Anders Brun, Erik Wernersson**
   Host: Mustafa Aslan
   Address: Risø, Denmark
   Date: 100506
   Topic: WoodFibre3D project

8. **Hamid Sarve, Vladimir Curic**
   Host: Nataša Sladoje
   Address: Centre for Mathematics and Statistics, Faculty of Technical Sciences, University of Novi Sad, Serbia
   Date: 100622–100623
   Topic: Research collaboration

9. **Ewert Bengtsson, Patrik Malm, Andreas Kårsnäs, Hamid Sarve**
   Hosts: Heung-Kook Choi and Kyeong-Ho Lee, president
   Address: Inje University, South Korea
   Date: 100820
   Topic: Collaboration Uppsala University and Inje University
   Comment: Visit to talk about relations between our two universities.

10. **Ewert Bengtsson, Patrik Malm, Andreas Kårsnäs, Hamid Sarve**
    Host: Heung Kook Choi, Inje university
    Address: Inje university, South Korea
    Date: 100815–100823
    Topic: Inje-Uppsala workshop on microscopy image analysis

11. **Khalid Niazi**
    Host: Mats Nilsson
    Address: Division of Toxicology, BMC, UU
    Date: 100818
    Topic: Blood flow measurement in blood vessels

12. **Ida-Maria Sintorn, Gustaf Kylberg**
    Hosts: Ali Mirazimi, Kjell-Olof Hedlund
    Address: Swedish Institute for Infectious Disease Control (SMI), Stockholm
    Date: 100922
    Topic: PanViruShield project meeting

13. **Hamid Sarve**
    Host: Ulf Olsson
    Address: Dept. of Economy, SLU
    Date: 100928
    Topic: Project-related Meeting
    Comment: Discussed statistical methods.

14. **Cris Luengo, Gunilla Borgefors, Erik Wernersson**
Host: Gary Chinga Carrasco
Address: PFI, Trondheim, Norway
Date: 100929
Topic: WoodFibre3D project

15. **Anders Brun**
Host: Ivanka Savic-Berglund
Address: Stockholm Brain, Karolinska Institutet, Stockholm
Date: 101007
Topic: MSc worker visit

16. **Hamid Sarve**
Host: Innventia, Stockholm
Address: Innventia, Stockholm
Date: 101028
Topic: Project-related Meeting

17. **Anders Brun, Ewert Bengtsson, Ulf Hammarqvist, Erik Wernersson**
Hosts: Michael Felsberg, Hans Knutsson
Address: ISY, Linköpings universitet, IMT, Linköpings universitet
Date: 101102
Topic: Visit to Linköping
Comment: Discussed SSBAs seniordag (Bengtsson and Brun). Wernersson and Hammarqvist discussed with Hans Knutsson about wavelets and filters.

18. **Anders Brun**
Host: Carl Henrik Ek
Address: School of Computer Science and Communications, Royal Institute of Technology, Stockholm
Date: 101116
Topic: Speaker, Thesis worker
Comment: Brun gave a talk at School of Computer Science and Communications, supervised G. L. Luo's master thesis work.

19. **Anders Brun**
Host: Bo Malmberg
Address: Öresundsbro, Uppsala
Date: 101118–101119
Topic: Workshop, Stockholm University, satellite imaging

20. **Ida-Maria Sintorn, Gustaf Kylberg**
Hosts: Gun Frisk, Monika Hodik
Address: Rudbeck Laboratory, Uppsala
Date: 101119
Topic: Detecting viruses using TEM
Comment: Discussing possible collaborations.

21. **About 20 CBA researchers**
Host: Anders Ynnerman
Address: Visualiseringscenter, Dept. of Science and Technology, Linköping University, Campus Norrköping
Date: 101216
Topic: Traditional "Lucia study excursion"
Comment: Our annual study visit this year went to see the recently inaugurated visualization center formed by the hosts and to discuss with them research topics of common interest.

7.12 Committees

Ewert Bengtsson
International:

- Editorial board member of the journal Machine Graphics & Vision, 1994–
  Comment: Published by Polish Academy of Sciences.
- Editorial board member of the journal Computer Methods and Programs in Biomedicine, 1995–
  Comment: Published by Elsevier.
- Senior member of the Institute of Electrical and Electronics Engineers (IEEE) 2004–
  Comment: Member since 1974.
- Member of the International Society for Optical Engineering (SPIE)
- Member of Eurographics, the European Association for Computer Graphics, 1998–
- Member of the International Society for Analytical Cytology (ISAC), 2000–
- Member of the European Research Council Advanced Grants Panel (ERC) 2008–
  Comment: During 2010 this appointment involved extensive review work and five days of panel meeting in Brussels.
- Member of the Labex-jury for the French research council, Comment: Taking part in the evaluation of a large number of large research proposals, Nov 2010- Feb 2011.
- Scientific committee for International Conference on Computer Vision and Graphics (ICCVG 2010), 100920–100922
- PhD dissertation committee for Frank Faas, 100517
  Comment: Served on the dissertation committee at Delft University, where the format is that the committee members also do the opposition.

National:

- Member of the Royal Swedish Academy of Engineering Sciences, Section VII: Basic and Interdisciplinary Engineering Sciences. 2006–
  Comment: (4 meetings)
- Vice Chair of Section VII of the Royal Swedish Academy of Engineering Sciences, 091119 –
  Comment: (3 meetings)
- Member of the Royal Society of Sciences in Uppsala (Kungliga Vetenskapssocieteten), 1998–
  Comment: Elected member of the oldest scientific society in Sweden. (5 meetings)
- Chair of Uppsala University IT Council, 2008–
  Comment: The IT Council is responsible for coordinating all aspects of IT usage and development at UU. The board has about 15 members. 6 meetings and additionally 6 preparatory and follow up meetings.
- Advisor to the Rector on Information Technology at UU, 1998–
  Comment: One of five advisor appointed to lead the strategic planning of UU and give advice to the Rector, taking part in the Deans-conference (2 meetings each 2 days).
- Member of the Board of UpGIS, the net for Geographical Information Systems at UU, 1999–
  Comment: (5 meetings.) Member of the reference group for UU IT-organisation review Comment: (4 meetings)
- Member of the UU student cooperation group, 2000–
  Comment: A group where the leadership of the university and the student unions meets to discuss matters of common interest. (3 meetings)
- Member of the scientific board of Hillevi Fries Research Scholarship Foundation.
  Comment: A Swedish foundation that accepts applications and gives out research grants for urology research. The board has three members. (1 meeting)

- On the reference group for Open Access Publications at UU 2008–
  Comment: (2 meetings)
- Non-voting member of the UU Library Board 2007–
  Comment: (4 meetings)
- On the Department Head Council of Polacksbacken, "Prefektrådet"
  Comment: (2 meetings)
- On the Department Head Meetings "Prefektmöten" SLU
  Comment: (3 meetings)
- On a reference group for Uppsala Learning Lab and an advisory group for the editor of the book summarizing 10 years of work promoting IT in learning *Comment:* (13 meetings)
- Auditor for Swedish Society for Image Analysis (SSBA), 2004–
- Chair of the Evaluation Panel for grant applications to the Swedish Research Council (VR): Natural and Engineering Sciences-Biomedical Engineering, 2009–
  Comment: Four full day meetings, about two weeks of full time work reading applications, more than 200 emails.
- Planning group for SSBA senior strategy day
  Comment: Meeting in Linköping 101102 to plan the new senior strategy day at SSBA conference March 16, 2011
- PhD committee of Shafiq ur Réhman, 100428
  Comment: Dissertation at UmeåUniversity Digital Media Lab, Department of Applied Physics and Electronics. Thesis title: Expressing Emotions Through Vibration.

Gunilla Borgefors
International:

- Fellow of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), 2007–
  Comment: Senior member since 1998.
- IEEE Computer Society Fellows Evaluation Committee, 2008–2010
- Fellow of the International Association for Pattern Recognition (IAPR), 1998–
- Member of the Advisory Committee of the International Association for Pattern Recognition (IAPR), 2008–2010
- Member of Nominating Committee of the International Association for Pattern Recognition, 2010–2012
- Area editor of the journal Pattern Recognition Letters, 2004–2010
  Comment: Editor-in-Chief from 110101. Published by Elsevier.
- Editorial Board member of the journal Image Processing and Communications, 1994–
  Comment: Published by the Institute of Telecommunications, Bydgoszcz, Poland.
- Editorial Board member of the journal Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications, 1993–
  Comment: Published by Interperiodica Publishing in cooperation with the "Cybernetics" Scientific Council, Russian Academy of Sciences.
- Editorial Board of the book series Computational Imaging and Vision, published by Springer, 2003–
- Programme committee for the Workshop on Application of on Digital Geometry and Mathematical Morphology (WADGMM 2010), Istanbul, Turkey, Aug. 2010
- Programme committee for International Conference on Computer Vision and Graphics (ICCVG2010), Warsaw, Poland, Sep. 2010
- Programme committee for the 15th Iberoamerican Congress on Pattern Recognition (CIARP 2010), Sao Paulo, Brazil, Nov. 2010

National:

- Royal Society of Sciences in Uppsala (Kungliga Vetenskapssocieteten), Member No. 19, 2000–
  Comment: Elected member of the oldest scientific society in Sweden (founded 1710), (5 meetings).
- Swedish Parliamentarians and Scientists, 1987–
  Comment: Members are elected. Only one scientist per field admitted.
- Nomination Committee, Swedish Society for Automated Image Analysis (SSBA) –2010
- Vice chair of Appointments board, Faculty of Forest Sciences, SLU, 1999–
  Comment: (9 meetings)
- The Prize and Reward committee of the Faculty of Forest Sciences, SLU, 2006–
  Comment: (2 meetings)
- Celsius-Linné committee, TN-faculty, UU, 2007–
  Comment: The committee selects the speakers for the annual Celsius and Linné lectures, (4 meetings).
- Member of the Board of UpGIS, the net for Geographical Information Systems at UU, 1999–
  Comment: Representing TN-faculty, UU.
- Expert committee for Swedish National Agency for Higher Education to evaluate if University Colleages should get Ph.D. examination rights., 2010
  Comment: The committee evaluated information technology at Halmstad and Skövde University Colleages. We had four days of physical meetings in Stockholm and a number of telephone meetings.
- Expert evaluator for the position of Assistant Professor in Imaging at MedTech West, Chalmers, Göteborg, 100401–100630
  Comment: 13 applicants.
- Expert for the promotion to Senior lector in Image Analysis and Processing at Royal Institute of Technology, Stockholm, 100501–101031
  Comment: The applicant was not successful, therefore the name is withheld.

Ingrid Carlbom
National:

- Chair of Board, Forskarskolan i Matematik och Beräkningsvetenskap (Graduate School in Mathematics and Computing), UU, 2004–2010
- Member, KK Stiftelsen's workshops on Future of Perceptualization, 2010–2011.

Joakim Lindblad
International:

- Technical Program Committee of the International Conference on Pattern Recognition (ICPR) 2010, Istanbul, Turkey
- Program Committee of the International Conference on Signal-Image Technology and Internet Based Systems (SITIS) 2010, Kuala Lumpur, Malaysia

Cris Luengo
International:

- Senior member of the Institute of Electrical and Electronics Engineers (IEEE) 2010
  Comment: Member since 2001.
- Member of the International Society for Analytical Cytology (ISAC), 2006–

National:

- Program Chair of the Swedish Symposium on Image Analysis (SSBA 2010), Uppsala, Sweden, March 10–12, 2010

Ingela Nyström
International:

- Member of the Executive Committee, International Association for Pattern Recognition (IAPR)
  - 2nd Vice President 2008–2010
  - Secretary 2010–
- Governing Board Member, International Association for Pattern Recognition (IAPR), 2002–2010
- Local Arrangements Chair for 5th EGEE User Forum 2010, Uppsala, Sweden, April 12–15, 2010
- Program Committee for Eurographics 2010, Norrköping, May 2010
- Program Committee for ICPR Workshop on Applications of Digital Geometry and Mathematical Morphology 2010, Istanbul, Turkey, August 2010
- Program Committee for 20th International Conference on Pattern Recognition (ICPR 2010), Istanbul, Turkey, August 2010
- Program Committee for 3rd Workshop on UnConventional High Performance Computing (UCHPC'10), Ischia, Italy, August 2010
- Programme Committee for 10th International Conference on Pattern Recognition and Image Analysis: New Information Technologies (PRIA-10-2010), St Petersburg, Russian Federation, December 2010

National:

- Board Member of Swedish Society for Automated Image Analysis (SSBA), 2000–
  Comment: President 2002–2006
- Board Member of the Swedish University computer NETwork (SUNET), 2008–
- Board Member of the Linnaeus Centre for Bioinformatics (LCB), 2009–2010
- General Chair of the Swedish Symposium on Image Analysis (SSBA 2010), Uppsala, Sweden, March 10–12, 2010
- Member of the Evaluation Panel for grant applications for Future Research Leaders at the Swedish Foundation for Strategic Research (SSF), 100125–100324
- Dissertation committee of Petter Bivall, Dept. of Science and Technology, Linköping University, Campus Norrköping, 101001
  Comment: Title: Touching the Essence of Life–Haptic Virtual Proteins for Learning.
- Dissertation committee of Magnus Gedda, CBA, UU, 100520
  Comment: Title: Contributions to 3D Image Analysis using Discrete Methods and Fuzzy Techniques: With Focus on Images from Cryo-Electron Tomography.
- Dissertation committee of Erik Gudmundson, Dept. of Information Technology, Div. of Systems and Control, UU, 100423
  Comment: Title: Signal Processing in Spectroscopic Applications.

Stefan Seipel
International:

- Program Co-Chair of Eurographics 2010, Shortpapers
- Program Committee Member for the 14th International Information Visualization conference, London, UK, 2010

National:

- Program Committee Member for the Annual Computer Graphics Conference SIGRAD 2010
- Board Member of the SIGRAD organisation, Svenska föreningen för grafisk databehandling, 2004–
- Faculty opponent for the licentiate thesis on "Computer Vision: From Motion Capture to Tabletop Interaction" by Tommaso Piazza, Chalmers University of Technology, June 2010.

Ida-Maria Sintorn
National:

- Board member of Swedish Society for Automated Image Analysis (SSBA), 2008–
  Comment: Treasurer from 2009.
- Member of the Evaluation Panel for grant applications to the Swedish Governmental Agency for Innovation Systems and the Swedish Civil Contingencies Agency programme "Security solutions with ICT"

Robin Strand
International:

- Program committee member, Workshop on Applications of Discrete Geometry and Mathematical Morphology, 100822–100825
  Comment: WADGMM was an ICPR 2010 pre-conference workshop.

National:

- Half-time review grading committee of Johan Berglund, Dept. of Radiology, UU, 101119
  Comment: Title: Magnetic resonance imaging of water and fat – advances in chemical shift based separation.
- Local Chair of the Swedish Symposium on Image Analysis (SSBA 2010), Uppsala, Sweden, March 10–12, 2010